Gyn. Staff Room University Hospital

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of a year and a half that the child could not be decannulated, the direct laryngoscopic appearances being about the same as when first examined. With a four weeks' interval between, I performed a ventriculocordectomy on each side. When seen one year later the child could cry almost as loudly as any child of its age. Direct laryngoscopy revealed a pair of adventitious cords closely resembling normal cords in color, but with a less range of motion. When the laryngoscope was introduced, the laryngeal orifice was closed tightly by the ventricular bands. When a deep inspiration took place, with the tracheotomic cannula corked, the ventricular bands would separate and reveal the adventitious cords. The mechanism of the cordal movement could not be determined. On theoretical grounds, I assumed that it was the result of activity of the crico-arytenoideus lateralis opposed by the resiliency of the scar tissue at the site of the operation, though the patient being a child I could not be sure that some degree of movement had not returned in the crico-arytenoideus posticus. A movement of the thyroid and cricoid cartilages in relation to each other may have contributed, as may also contraction of the arytenoideus.

CASE 7.—*Tabetic Bilateral Abductor Paralysis.*—A man, aged 56, after exposure overnight in the rain during alcoholic stupor, six months before admission, discovered that he was very hoarse. The night before admission he awoke struggling for air. He thought he would "choke to death" before morning. He was carried into the hospital sitting upright on the gripped hands and wrists of two men, keeping himself upright by holding to their shoulders with his hands. He had fallen from weakness, becoming "blind" and almost unconscious, on attempting to walk. He was blue-black in color and the stridor could be heard all along the corridor. He was carried to the operating room, repeating over and over, "Don't lay me down; I'll choke." For temporary relief I inserted a bronchoscope while he was in the sitting position to avoid laying him down. To attempt even local anesthesia would have been a fatal mistake and would have been quite unnecessary. The bronchoscope completely relieved the dyspnea and went deeply into the trachea without resistance. It was noted that the larynx was engorged with cyanotic blood; the cords were in contact, but not otherwise abnormal. I then performed a low tracheotomy with the bronchoscope in situ. The next day the patient was examined thoroughly; the station, gait and reflexes pointed clearly to a tabes that evidently had antedated the paralysis of the first cord, which probably was the cause of the hoarseness noticed six months previously. The Wassermann examination was negative. Spinal fluid Wassermann examinations were not then in vogue. Rest, mercurial iodids, good food and abstention from alcohol in six months had so greatly improved all the tabetic symptoms that only careful examination could demonstrate them. The patient was very desirous of getting rid of the cannula. He stated that even if he had only a few years to live he did not "want to live this way." At the end of a year after the tracheotomy, there being no improvement in the laryngeal stenosis and no exacerbation of the tabetic symptoms, I consented to perform a ventriculocordectomy. One side was operated on at a time, three weeks intervening between the two. During an attack of infective epidemic tracheobronchitis the patient could cough and expectorate as well as before operation. The voice, at first a whisper, became a "stage whisper" in a few months. When last seen, about a year after operation, he was able to phonate so as to be heard in the adjoining room. The tabes had progressed somewhat in spite of constant treatment.

CONCLUSIONS

1. In ventriculocordectomy I believe we have a simple endoscopic operation that can be performed under local anesthesia and that will cure almost every patient with laryngeal stenosis that is due solely to abductor paralysis, if the case is not complicated by a faulty tracheotomy.

2. Ventriculocordectomy is indicated in cases of stenosis resulting from a hopelessly paralyzed larynx.

3. This or any other form of operative clearing of the airway is contraindicated in the first six months of abductor laryngeal paralysis. In most cases it is wise to wait a year.

4. The best means of affording relief of dyspnea and safety of the patient during this waiting period is by prompt *low* tracheotomy. High tracheotomy is the cause of more cases of cicatricial laryngeal stenosis than any other one thing. With a low tracheotomy, a pair of proper cannulas and a daily toilet of the fistula, there is nothing lost by waiting.

5. Out of eighteen cases in which ventriculocordectomy was performed the seven that were uncomplicated by cicatricial stenosis were afforded satisfactory relief of dyspnea by this procedure alone. One required divulsion in addition.

6. The chief functions of the larynx are phonetic, protective and expectorative. Considered in the light of the degree of preservation of these functions, ventriculocordectomy not only surpasses any previously devised operation, but is simply ideal for those cases in which neural and muscular atrophy has rendered resumption of normal cordal motility hopeless by either spontaneous recovery or neuroplastic surgery.

128 South Tenth Street.

PAPILLOMA OF THE LARYNX IN CHILDREN

A REPORT OF ELEVEN CASES *

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Virchow,[1] in 1863, and later Stoerk,[2] in 1880, classified laryngeal papilloma as a benign tumor of connective tissue origin and suggested that the generic name for the tumor should be "fibroma," with the term "papillary" used as a descriptive adjective. This led to a long controversy as to whether there should be any pathologic distinction between a true papilloma of connective tissue origin and a papillary hypertrophy of epithelial origin.

It may be difficult to distinguish between these conditions histologically; but clinically, the difference is very striking. Papillary hypertrophy is commonly seen in adults; is almost invariably located in the posterior half of the larynx, and is the result of a chronic irritation of the mucous membrane due to syphilis, tuberculosis or a long-standing catarrhal inflammation. The true papilloma, on the other hand, is most frequently found in young children and is sometimes congenital. The growth may arise from the vocal cords or from any part of the mucous membrane of the epiglottis, larynx or trachea. Its most striking characteristic is the rapid recurrence after removal and the tendency to transplant itself to any adjoining area of mucous membrane that may be injured during operation.

Microscopically, the papilloma consists of a branched connective tissue framework, which is well developed in the flatter types, but less marked in the more elongated types of the growth. This connective tissue framework contains arteries and veins, and, according to Harmon Smith, nerve fibers. The outer layers of epithelium vary in type and thickness. Sometimes, there are many layers of squamous cells, with a typical horny layer on the surface, while in other specimens, the epithelium is columnar. The size and arrangement of the cells, the appearance of the nuclei, the presence of a basement membrane, and the absence of invasion into the central connective tissue framework all differentiate the benign from the malignant papilloma. These changes should be particularly looked for at the point of attachment of the tumor.

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* From the Surgical Clinic of the Johns Hopkins Hospital.

1. Virchow: Die krankhaften Geschwülste, Berlin **1**:1863. Spec. Path. u. Therap., Nothnagel **13**:234.

2. Stoerk, Carl: Klinik der Krankheiten des Kehlkopfes, der Nase und des Rachens, Stuttgart, 1880, p. 396.

Schrötter [3] offers an interesting explanation for the retrogressive changes that may account for the spontaneous disappearance of a papilloma. He believes that the location of the tumor and its mobility result in an injury to the delicate vessels that supply it. The injury may be in the form of a ruptured vessel with an extravasation of blood throughout the connective tissue framework, or a twisted pedicle that leads to thrombosis. He describes specimens in which there are accumulations of yellowish brown pigment and isolated fat droplets.

Unlike the benign papillary tumor of the larynx in adults, this type of growth in children is very difficult to cure. The difficulties of treatment by operative removal are due to: (1) the small lumen of the larynx and trachea in children; (2) the tendency of the growth to recur locally after excision and, in addition, to transplant itself to adjoining areas of mucous membrane that were free from growth before the operation, and (3) the necessity for tracheotomy in nearly every case. As a rule, the tracheal tube must remain in place for months or years and this may further complicate the cure of these cases, as will be more fully discussed later.

Fortunately, laryngeal papilloma is not common in children; but unless it is recognized early and treated intelligently and conservatively, it is certain to result either in death from suffocation or in a fibrous stenosis of the larynx. The rarity of the affection is shown by the following statistics: Rosenberg, in 1896, from Fränkel's clinic in Berlin, reported sixteen cases of papilloma of the larynx that had been observed in a series of 5,808 children under 13 years of age. Schrötter found only ten cases among 7,324 children under 10 years of age. Only twenty-three cases were seen in Chiari's [4] clinic in Vienna during the twenty years from 1892 to 1912. The records of the Massachusetts General Hospital [5] indicate that the incidence of papilloma of the larynx is approximately 1:1,000 in children under 14 years of age. Harmon Smith,[6] in 1914, reported the eight cases that had been seen at the Manhattan Eye, Ear and Throat Hospital during a period of fifteen years. At the Johns Hopkins Hospital, we have seen, since 1912, only eleven cases. A review of the literature indicates that the mortality rate of papilloma of the larynx in children under 5 years of age is equal to, if not greater than, that of carcinoma of the larynx in adults.

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3. Schrötter, L.: Vorlesungen über die Krankheiten des Kehlkopfes, Vienna, W. Braumüller, 1892, p. 269.

4. Chiari, O.: Papillome im Larynx der Kinder, Wien. med. Wchnschr. **63**:2468-2475, 1913.

5. Clark, J. P.: Papilloma of the Larynx in Children, Tr. Am. Laryn. Assn. **27**:185-199, 1905.

6. Smith, Harmon: Papilloma of the Larynx, J. A. M. A. **63**:2207-2211 (Dec. 19) 1914.

The papilloma, while rare, is still the most common type of new growth in the larynx of children. This growth may appear at any age, and according to Gerhardt [7] approximately one fifth of the cases in young children are congenital. Boys are more frequently affected than girls. In our series, every case was in a boy.

Nothing definite is known concerning the etiology. The infectious diseases that are associated with a lesion on the mucous membrane of the upper air passage, such as measles, chickenpox, scarlet fever and diphtheria, and the diseases that cause excessive coughing, are all regarded as etiologic factors. The general hygienic surroundings of the child may be of etiologic importance. All of our cases were from the class of people that apply to the free dispensary for treatment. Children of this class are exposed to dust, extremes of heat and cold, are improperly fed and are certainly more prone to chronic catarrhal conditions of the upper air passage than are the children that receive better care. It has never been proved that syphilis, tuberculosis or gonorrhea are responsible for the presence of these growths in newborn infants.

Possibly the best method of gaining a clear idea of the seriousness of this condition in children and the successes and failures of the various methods of treatment is to relate in some detail the clinical experience of laryngologists in this country and in Europe.

Elterich [8] reports the case of a child, aged 2 years, with complete aphonia, and a history of hoarseness and attacks of dyspnea that were first noticed at 7 months of age. The parents would not consent to an operation of any kind; and a few days later the child died of asphyxia before a physician could reach the home. The larynx and upper part of the trachea were opened and found to be almost entirely occluded with papillomatous growths.

Broca and Roland [9] conclude that no method of treatment is satisfactory in all cases. The papillomas of the larynx come and go in the arbitrary and mysterious manner of warts on the skin. They sprout as if grown from seed sown by the primary source and behave in the larynx in much the same way as do papillomas in the bladder. Removal of the growths through the mouth is preferable to any other method of treatment; but, as a rule, the operation must be repeated during months or even years. Even if the growth is cured by tracheotomy, thyrotomy or laryngostomy, a fibrous stricture of the larynx often necessitates a permanent tracheotomy or, at least, a long and tedious

7. Gerhardt: Kehlkopfgeschwülste, Spec. Path. u. Therap., Nothnagel **13**:16.
8. Elterich, T. J.: Papillomata of the Larynx in an Infant, Arch. Pediat. **21**:840-843, 1904.
9. Broca and Roland: Traitment des papillomes du larynx chez l'enfant, Rev. de chir. **43**:281-301, 1911.

series of treatments in order to reestablish breathing through the normal passages.

In addition to the danger of suffocation from the growth, there is danger of a suddenly fatal inhibiting reflex. Broca and Roland quote a case of papilloma of the larynx reported by Boris Frankel, in which a child of 6, with no history of dyspnea, developed symptoms of laryngeal obstruction suddenly during the night and died within a few minutes. They also give the statistics of the forty-eight cases compiled by P. Bruns: More than half the children died before the age of 3, and only five reached the age of 10 without operation.

The spontaneous subsidence of the papilloma may explain the cure in some cases; and the possibility of this justifies expectant treatment for a reasonable time after tracheotomy.

We agree with the following generalizations of Broca and Roland. If a child has dyspnea, a tracheotomy should be performed as soon as the condition is recognized, and should precede all other therapeutic measures. It is of the greatest importance to bear in mind two points: (1) The tracheotomy must always be performed under local anesthesia. (2) The opening in the trachea must be midway between the isthmus of the thyroid and the top of the sterum. The reasons for these two points are fully discussed later.

McCoy [10] reports the case of a boy, aged 5 years, whom he saw in October, 1912. There was a history of increasing hoarseness for two years, and dyspnea for six months.

Oct. 10, 1912, under chloroform anesthesia, a large mass of papilloma was removed with the aid of a direct laryngoscope. The entire larynx was involved, both above and below the cords. The respiration became practically normal after the operation.

October 19, operation was again necessary on account of the rapidly increasing dyspnea. Tracheotomy was performed; and again large masses of papilloma were removed by endolaryngeal methods.

March 17, 1913, the entire larynx was filled with growth. It was decided to try the combination of surgical removal and fulguration. The growths were excised and their point of attachment fulgurated, once each month, from March, 1913, to June, 1914. The tracheal tube which had been worn for fifteen months was removed in June, 1914; and at the time of the last note, four months later, there was considerable hypertrophy of the laryngeal tissues but no recurrence of the papilloma.

This case illustrates the marked tendency of these growths to recur after surgical removal. In general, it is not advisable to use chloroform, when a series of operations is necessary, on account of its

10. McCoy, J. B.: A Case of Multiple Laryngeal Papillomata in a Child Treated by Direct Laryngoplasty and Fulguration, Internat. J. S. **28**:116, 1915.

toxic effect; but, in this case, it was the only general anesthetic that would permit the use of the high frequency spark.

Our experience has shown that it is always wise to leave the tracheal tube in place for several months after the papillomas have apparently disappeared. One of our patients (Case 3) died on the train on which he was returning to Baltimore. In this case, the growths had been removed; their points of attachment fulgurated on four occasions, and, finally, the interior of the larynx treated with 100 mg. of radium on two occasions, once for one hour and again for one and one-half hours. On direct inspection, the larynx seemed to be free from growths, and the tracheal tube was removed. Dyspnea came on suddenly, six months later, and the child died before he could reach the hospital. Necropsy demonstrated that the entire larynx was filled with growths.

Harris[11] reports the case of a boy, aged 11, who was suspected of having tuberculosis on account of dyspnea, hoarseness and fever. There was a history of measles and pneumonia; but otherwise he had always been well. The examination of the chest was negative. A papilloma situated below the vocal cords was discovered on direct laryngeal examination. Attempts to remove the tumor endolaryngeally under local anesthesia, and later under ether, were not successful. It was decided to remove the growth by an external operation; but before they were ready to open the trachea, the child stopped breathing and an emergency tracheotomy through the cricothyroid membrane was necessary. Further operation was then abandoned, and the patient was returned to the ward. It was feared that a permanent cicatricial stenosis would result on account of the high tracheotomy. Two months later, however, the edema had subsided and it was found that the growth had disappeared. The tube was removed. The voice became clear and strong, and, at the time of the last note, he was apparently well.

This case emphasizes the danger of giving a general anesthetic to a patient with an obstruction anywhere in the trachea or larynx. The tracheotomy must always be performed under local anesthesia.

Other cases have been reported in which the growth disappeared after a tracheotomy; but, in the great majority of the reports, additional measures have been necessary. The fact should not be ignored, however, that some of these children have been cured by tracheotomy alone; this suggests a safe, simple and conservative form of treatment.

In Sargnon's[12] case, that of a child, aged 5, there was a history of dyspnea for one and one-half years and recently attacks of suffocation.

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11. Harris, T. J.: A Case of Subglottic Papilloma Cured by Laryngotracheal Fistula, Tr. Am. Laryngol. Assn. **30**:28-31, 1908.

12. Sargnon: Papillomes récidivants du larynx; papillomes intrathoraciques; curettages endoscopiques, Lyon méd. **114**:1003, 1910.

Under general anesthesia, the papillomas were removed through the mouth, on several occasions. After each operation, they recurred rapidly and finally involved the epiglottis and the subglottic area, which were originally free from growth. A tracheotomy tube was then introduced; but in a short time, the papillomas had grown downward into the trachea to such an extent that further measures were necessary. Sargnon repeatedly removed the growths in the trachea, using a local anesthetic and a bronchoscopic tube. After each operation, they recurred and involved the trachea at a lower level. Finally, the left bronchus was involved; and in spite of frequent operations, the child died.

Fortunately, not all cases of papilloma of the larynx exhibit this tendency to spread. Some of the benign papillomas of the urinary bladder in the adult transplant themselves to apparently normal mucous membrane after surgical removal of the original growth, and each operation results in an increase, until finally the bladder is filled with tumor. These bladder papillomas are now cured by fulguration or radium applied through a cystoscope. It was hoped that similar measures would be equally successful in the treatment of laryngeal papilloma.

The local application of radium is perhaps the best method of treatment for a benign papilloma of the larynx in an adult; but in children, both fulguration and radium have so far given disappointing results. It is probable, however, that further experience with the use of radium in these cases will establish a more suitable dosage and method of application than we now possess.

Payson Clark [5] reports fourteen cases from the Massachusetts General Hospital. Of these, nine were in boys and five were in girls. The symptoms dated from birth in one case; and in another, the trouble was first noted when the child was 3 months of age. Of the remainder, five were under 2 years of age. Treatment without previous tracheotomy was attempted in four cases. One of the children died during the operation; one never returned after the first operation; one was cured, and in one, after several successful operations, an emergency tracheotomy was necessary for a sudden attack of dyspnea. Preliminary tracheotomy was performed in each of the remaining ten cases. Of these patients; four died, three of pneumonia and one of suffocation, due to a recurrence of the growth after the condition had been apparently cured and the tube removed. In a later paper, Clark [13] gives the details of some cases that well illustrate the difficulties of treatment.

In Case 9, that of a boy, aged 6 years, who had suffered from hoarseness and dyspnea for one year, tracheotomy, with removal of the papillomas through

13. Clark, J. P.: Papilloma of the Larynx in Children—A Further Consideration of the Subject, Tr. Am. Laryn. Assn. **30**:283-299, 1908.

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the mouth, was performed in February, 1901. In October, 1901, the larynx was again filled with growth. Large masses of papilloma were removed. February, 1902, no papilloma was found above the vocal cords; but there was a large mass below the cords. Nothing was done. Frequent examinations during the next two years showed that the growth was slowly diminishing in size. In June, 1905, under ether anesthesia, the remaining growths were removed from the larynx and trachea by means of a Killian tube introduced through the tracheotomy opening. March, 1906, the larynx and trachea were free from growth. The tracheotomy tube was removed, and the tracheal opening closed. Two years later, there was no recurrence.

In Case 10, that of a boy, aged 9 years, with a history of hoarseness for six months and dyspnea for two weeks, tracheotomy was performed in August, 1904; but no growth was removed at this time. In September, 1904, and February, 1905, large masses of papilloma were removed; but they rapidly recurred, and further operation was abandoned. May, 1906, the growths in the larynx had shown no tendency to spread and had not increased in size. Under ether anesthesia, the remaining papillomas were removed. The tube was removed after having been worn for one year and nine months. June, 1907, there had been no recurrence. The vocal cords were normal in appearance and the voice was good.

In Case 14, that of a girl, aged 2 years, with a history of hoarseness and dyspnea, and in whom the larynx was almost filled with papillomas, a tracheotomy was performed in August, 1904. In October, 1904, the growth was thoroughly removed through the mouth. In February, 1905, the larynx was again filled with growth, so it was decided that further operation at that time was not advisable. In September, 1905, papilloma was appearing at the tracheal opening when the tube was removed. No operation was performed. In January, 1906, while changing the tube, the child was nearly asphyxiated, owing to closure of the tracheal opening with papilloma. A portion of the growth was removed. In March, 1907, July, 1907, and February, 1908, it was necessary to remove the growth around the tracheal opening. In April, 1908, the growth had not recurred in the trachea. The tube was removed. In September, 1908, the larynx and trachea were free from growth.

These cases show that a cure may be obtained without recourse to radical surgical operations. Our experience has convinced us that an external operation for papilloma of the larynx in children is never justifiable. The growth may be cured by this method; but a stenosis of the larynx results.

An early tracheotomy is necessary. The growth should be removed through the mouth and under direct vision. A Jackson laryngoscope or a swinging laryngoscopy apparatus may be used. Care must be taken not to injure the surrounding mucous membrane. Even sponging with gauze or cotton will, in some cases, result in a spread of the growth. Actual or chemical cauterization should be avoided; they will not prevent recurrence, and will result in scarring or stricture.

Tracheotomy, removal of the growths when necessary, the careful use of the roentgen ray and radium, general hygienic measures, and, above all things, patience, are the essential features in the therapy of papilloma of the larynx in children.

Harmon Smith[6] reports the case of a boy, aged 3½ years, who had complained of severe attacks of hoarseness and dyspnea for eighteen months and in whom the entire larynx was filled with papillomas.

From July 11 to Sept. 12, 1912, the growths were fulgurated on six occasions under chloroform anesthesia. After each of these treatments, the tumors would disappear but would recur rapidly. September 12, it was decided to make a severe test of this method of treatment. The local reaction, however, was so marked that a tracheotomy was necessary five days later. The larynx was then treated with another series of fulgurations, but with no permanent benefit. Jan. 20, 1913, about 4 a. m., the child pulled out the tracheotomy tube and died from asphyxia before the house surgeon could reach the ward.

We could add an indefinite number of cases from the literature on this subject; but these few illustrate clearly the difficulties encountered in the treatment of this condition.

TRACHEOTOMY IN CHILDREN

The one important method of treatment of papilloma of the larynx is the introduction of a tracheal tube. Before discussing this, however, in relation to the treatment of papilloma of the larynx in children, we will digress from our original topic long enough to point out the dangers and complications that may arise from this apparently simple operation.

Chevalier Jackson[14] has recently called attention very forcibly to the *discouraging end-results* of the tracheotomies that have been successful in their primary object of tiding the patient over a critical period. He states that throughout the period of thirty-four years in which he has been interested in the treatment of chronic laryngeal stenosis, at least five sixths of the total number of his cases of chronic stenosis have been due to faulty tracheotomy or improper postoperative care. This is in marked contrast to the results in his own series in which more than 100 patients were tracheotomized for some acute laryngeal condition without the occurrence of a single case of chronic laryngeal stenosis as an end-result. In other words, if a tracheal tube is properly inserted, it will not only save the patient's life, but will prevent the months or years of tedious and painful treatment that are often necessary in order to remove the tube and reestablish breathing through the larynx.

The main points to bear in mind in order to perform a safe tracheotomy are:

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14. Jackson, Chevalier: High Tracheotomy and Other Errors, the Chief Causes of Chronic Laryngeal Stenosis, Surg., Gynec. & Obst. **32**:392-398 (May) 1921.

1. A patient with obstructive dyspnea should *never* be given a general anesthesic in order to introduce a tracheal tube. Jackson states that of the thirty surgical textbooks examined in regard to this point, all mentioned general anesthesia, but not one condemned it. A dyspneic patient depends on the aid of his accessory respiratory muscles. When he passes under the influence of a general anesthetic, he loses this accessory aid and suddenly becomes cyanotic or respiration ceases. Infiltration of the skin with a 1:400 solution of procain, to which is added a few drops of epinephrin, will make the operation practically painless. Even when the operation is performed under local anesthesia, we do not think it wise to try to abolish the cough reflex by the administration of narcotics or the intratracheal injection of cocain, as recently recommended by St. Clair Thomson.[15]

2. A *low tracheotomy* is the operation of choice; and in children, it is the only location in which a tracheal tube should be inserted. There are many reasons for this:

(*a*) Division of the cricoid cartilage removes the only ring support of the larynx, and also interferes with the subsequent development of the larynx. Perichondritis due to secondary infection is more likely to occur after division of the cricoid than it is when the tracheal rings are divided.

(*b*) The subglottic space is the narrowest portion of the larynx and the inevitable secondary infection and granulations that result from the wearing of a tube over a long period results in stenosis. Even if the cricoid is not divided and the opening is made through the first and second rings of the trachea, the tube is still too near the subglottic space; and fibrous laryngeal stenosis is likely to result.

(*c*) The thyroid isthmus in a child lies much higher than in an adult; and, in addition, it is firmly adherent to the trachea. This offers another complication to high tracheotomy, especially if the operation is performed rapidly.

(*d*) In performing a low tracheotomy, care must be taken not to make the opening in the trachea too low. If a roll is placed under the patient's shoulders and the head retracted, about 1 inch (2.5 cm.) of the thoracic trachea is drawn upward into the neck. It is easy under these conditions to insert the tube so low that when the patient assumes the upright position it will be found that the tracheal opening is below the sternal notch. This results in a poorly fitting tube, subcutaneous emphysema, and often a mediastinal infection. If properly performed, however, a low tracheotomy is as quickly and as safely performed as the high operation.

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15. Thomson, St. Clair: Tranquil Tracheotomy by Injecting Cocain Within the Windpipe, J. A. M. A. **73**:1032-1033 (Oct. 4) 1919.

Neumann[16] reports 133 cases of high tracheotomy, in 9 per cent. of which a laryngeal stenosis resulted, and 292 cases of low tracheotomy in only 1 per cent. of which a stenosis developed.

3. If the mechanical principles are ignored and the after-care of the wound and tube is neglected, a stricture is likely to result even with a low tracheotomy. The cartilaginous rings do not extend around the entire circumference of the trachea; the posterior wall has no rigid support. When the cartilages are divided anteriorly and spread apart for the introduction of a tube, the posterior wall bows forward and materially reduces the lumen of the trachea. If the tube does not have the proper curve, or if it contains the utterly useless fenestra in its posterior wall, an ulcer may form on the posterior wall of the trachea and cause a stricture.

It is not uncommon to have serious complications result from a badly fitted tube. Roger[17] reported twenty-two cases in which necropsy disclosed ulcerations of the tracheal wall due to pressure of the tube. The decubitus was on the anterior wall, opposite the tip of the tube in sixteen, on both the anterior and posterior wall in four, and on the posterior wall in two. Taute[18] collected the reports of seventy-two cases of fatal hemorrhage after tracheotomy. The bleeding was due to the erosion of the tracheal wall, and secondarily of one of the large vessels by the constant pressure of the end of the tube. Of these seventy-two cases, the innominate artery was eroded in fifty-five, the common carotid in four, the inferior thyroid artery in three, and the innominate and inferior thyroid veins in two.

4. Subcutaneous emphysema is an occasional early complication of a tracheotomy. It is due to certain conditions:

(*a*) The opening in the trachea is larger than the tube and the escaping air spreads along the fascial planes in the neck. This applies to either a vertical or a transverse incision in the tracheal wall.

(*b*) The tube is too short and is coughed out of the trachea.

(*c*) If emphysema once appears as a result of either of these causes, the swelling of the tissue will cause an otherwise well-fitting tube to become too short. The tube may be coughed out and thus favor the spread of the emphysema. Mediastinal emphysema usually results in the death of the patient.

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16. Neumann, A.: Mitteilungen über Diphtherie, Deutsch. med. Wchnschr. **19**:154-157, 1893.

17. Roger, quoted by Chiari: Chirurgie des Kehlkopfes und der Luftröhre, Neue Deutsche Chirurgie, Stuttgart, F. Enge **19**:109, 1916.

18. Taute, quoted by Chiari: Chirurgie des Kehlkopfes und der Luftröhre, Neue Deutsche Chirurgie **19**:103, 1916.

5. The use of a trocar to perform an emergency tracheotomy is never justifiable. The use of a cautery to divide the skin and tissue overlying the trachea is dangerous on account of delayed hemorrhage.

6. The excision of a piece of the tracheal wall the size of the tube is followed by an excessive formation of granulations and a local stricture at this point is apt to result when the tube is removed (Chiari).

Methods of Treatment

The fact that there are so many methods of treatment for papilloma of the larynx in children indicates clearly that the therapy of this condition is universally unsatisfactory. The principal forms of treatment have been indicated in the preceding illustrative cases from the literature. For the sake of clearness, however, we will review the therapeutic measures that have been advocated and add the results of our experiences.

Tracheotomy without local treatment

Hansberg [19] reports a series of cases, all of them were children that were treated by tracheotomy alone. "Good results" were reported in seven cases; in three, the tube was worn for six months; in one, for two years; in one, for seven years, and in one the time is not mentioned. "No results" were reported in four cases. One child died of pneumonia. In two cases, the tube was worn for seventeen and twenty-two years, and the growths finally were removed endolaryngeally.

Ferreri [20] describes a case, in a girl 3 years of age, in which tracheotomy was performed and the tube left in for "several months" in order to see whether the tumors would disappear as some authors assert. "On the contrary they increased in size." Operative removal ultimately resulted in a cure. The duration of the cure is not mentioned.

Gray [21] reports the case of a child, 3 years of age, in which a tracheotomy was performed in July, 1905. In July, 1906, the growths had involved the trachea, and the dyspnea was marked. Roentgen-ray treatments throughout the next two years resulted in an apparent cure. Gray also describes another case, in a boy of 6, in which there was no improvement in the laryngeal condition two years after the introduction of the tracheal tube.

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19. Hansberg: Handbuch d. Spez. Chirurgie und der oberen Luftwege, Würzburg **4**:395, 1913.

20. Ferreri, G.: Procédés d'excision des papillomes laryngiens, Arch. internat. de laryngol., otol., etc., Paris **32**:1-6, 1911.

21. Gray, A. L.: Remarks on the X-Ray Technic in the Treatment of Laryngeal Papillomata in Children, Ann. Otol., Rhinol. & Laryngol. **19**:348-350, 1910.

Bruns [22] reports the cases of twenty-six patients treated by tracheotomy alone, with seven deaths and nineteen patients improved.

Langmaid,[23] of Boston, described the case of a child, aged 5, in whom tracheotomy alone was followed by a cure after five years.

Broca and Roland conclude that tracheotomy and rest will not cause the growths to disappear.

Harmon Smith concludes that a tracheal tube without some collateral aid will *not* result in the disappearance of the growth.

Payson Clark is a strong advocate of tracheotomy and noninterference locally—"while a cure is possible in a large number of cases by simple tracheotomy and time, removal of the papilloma (intralaryngeally) when it has become quiescent hastens the cure."

Dungas Grant [24] reports a case in which a girl underwent a tracheotomy when four months of age. At the age of 22 years, she was still wearing a tube and the larynx was filled with papillomas. These growths were removed at one sitting and never recurred.

A tracheotomy was necessary sooner or later in every case of papilloma of the larynx in a child that we have seen. As soon as a diagnosis is made, the first step in the therapy should be the introduction, under local anesthesia, of a well placed, carefully fitted tracheal tube. An intubation tube cannot be used with safety in this condition. Several cases have been reported in which the introduction of an intubation tube was followed by bronchopneumonia, presumably due to the aspiration of a piece of the growth.

OPERATIVE REMOVAL

There are three methods of operative removal: (*a*) endolaryngeal removal; (*b*) laryngofissure with immediate closure, and (*c*) laryngostomy or permanent opening of the larynx.

The last two methods are probably never justifiable in a child. Either of these two procedures may result in a cure of the papilloma; but an even worse condition—a laryngeal stenosis—is substituted (Case 1 of our series).

Endolaryngeal removal is the operation of choice, and every writer has emphasized the importance of traumatizing as little as possible the mucous membrane adjoining the growth. Trauma certainly encourages the multiplication and spread of these laryngeal papillomas.

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22. Bruns, P., quoted by Chiari: Chirurgie des Kehlkopfes u. der Luftröhre, Neue Deutsche Chirurgie **19**:360, 1916.

23. Langmaid, in discussion on Coakley: Tr. Am. Laryngol. Assn. **29**: 126-141, 1907.

24. Grant, Dungas: The Etiology, Treatment and Prognosis of Innocent Laryngeal Growths, J. Laryngol., Rhinol. & Otol. **19**:637-652, 1904.

It has been the general experience that repeated removals are necessary over a long period of time in order to effect a cure. Dr. Robert Lynch,[25] however, seems to have had extraordinary success by removing the growths with the aid of his suspension apparatus. He reports sixteen cases of papilloma of the larynx (six in children under 5 years of age), in all of which the voice returned perfectly. The growths in children were all multiple. He did not operate after the period of active growth had ceased, but took the cases just as they came. No local applications were used, other than tincture of benzoin at the time of operation.

Dan McKenzie[26] reports one case, in a boy aged 7, in which the papillomas had been removed several times by the usual intralaryngeal methods, but always with recurrence. One removal with the suspension apparatus resulted in an apparent cure, since there has been no recurrence in a year.

Albrecht has had uniformly good results after removal with the suspension apparatus in nine children.

Dr. Robert Levy,[27] of Denver, reports the case of a child, 8 months of age, in which a localized growth in the anterior commissure was removed under direct suspension. This was thought to be a particularly favorable case; but the growth rapidly recurred with "increased activity."

The experience of the great majority of French, German, Austrian, English, Italian and American writers is that when the growths are removed endolaryngeally with any kind of curet or forceps, they almost invariably recur, and the operation must be repeated throughout months or years.

OTHER METHODS

Fulguration gives such favorable results in the treatment of papilloma of the bladder that it has been given an extensive trial in papilloma of the larynx. The results, however, are unsatisfactory. Several of our patients were anesthetized with chloroform, and the high frequency spark applied under direct vision. The improvement has always been temporary. Removal with an electric cautery not only fails to cure but results in a fibrous stenosis of the larynx. The local application of alcohol, recommended by Delavan, Chevalier Jackson and others, is apparently of value in some cases. The use of formaldehyd, castor oil, the chemical caustics and astringents is of

25. Lynch, R. C., in discussion on Hubbard: Tr. Am. Laryngol. Assn. **37**: 52-66, 1915.

26. McKenzie, Dan: Papilloma of the Larynx in a Child Treated Under Suspension Laryngoscopy, Proc. Roy. Soc. Med. **9**:Laryngol. Sect., p. 53, 1915.

27. Levy, Robert, in discussion on Smith, Harmon: Papilloma of the Larynx, J. A. M. A. **63**:2207-2211 (Dec. 19) 1914.

little value. The internal administration of arsenic, potassium iodid, calcined magnesia, and tincture of thuja each has a few enthusiastic adherents. Many encouraging results of roentgen-ray and radium treatment have been reported from this country and Europe. Great caution must be used, however, in the administration of these agents, and particularly in the intralaryngeal application of radium.

Duffy [28] reported in detail the postmortem findings in one of our cases (Case 4) in which the intralaryngeal application of radium resulted in a sloughing of the posterior laryngeal wall and a tracheo-esophageal fistula *without causing a disappearance of the papilloma.* The amount of radium used in this case was: Sept. 28, 1915, 103 mg. of radium for forty-five minutes; November 5, 103 mg. of radium for one hour and thirty minutes; November 20, 103 mg. of radium for two hours, and December 20, 103 mg. of radium for one hour and fifty-five minutes.

Jan. 1, 1916, the tracheotomy tube was removed. January 13, there was difficulty in swallowing, and February 5, bronchopneumonia developed. The patient died ten days later.

Since this experience, we have never employed radium without the expert advice of Dr. C. F. Burnam, and we have had no further burns; but on the other hand, it is doubtful whether or not we have had a permanent cure. Case 8 is a good example. The patient was anesthetized for each treatment, and the radium applied to the growths under direct vision.

Dec. 13, 1917, 500 mc. was applied for five minutes; Jan. 3, 1918, 600 mc. was applied for one and three-fourths minutes; January 19, 542 mc. was applied for three and one-half minutes, and February 9, 1,065 mc. was applied for three minutes.

During March the patient had whooping cough without complications. June 15, a heavy external radiation was applied over the front and both sides of the larynx. November 20, 700 mc. was applied for five minutes; Jan. 23, 1919, large masses of papillomas were removed through the mouth and tracheal opening. February 10, 879 mc. was applied to the larynx through the tracheotomy opening for ten minutes. November 21, 700 mc. was applied to the larynx from above for ten minutes. In addition to these intralaryngeal treatments, several heavy external radiations were applied.

Jan. 20, 1920, large masses of papilloma were excised from the larynx and trachea. June 21, large masses of papilloma were excised from the larynx and trachea. June 8, 1921, large masses of papilloma were excised from the larynx and trachea. September 15,

28. Duffy, W. C.: Papilloma of the Larynx, Johns Hopkins Hospital Reports **18**:417-438, 1919.

the patient breathed freely with the tube corked. Small masses of papilloma were removed from the trachea.

Plum,[29] from Schmiegelow's Clinic in Copenhagen, has recently reviewed the literature of papilloma of the larynx in children, and gives a list of eighty-four references. Very few articles have appeared on this subject since 1914. While the results have been encouraging in isolated cases, sufficient data have not been collected regarding the amount of radium used, the method of application and the ultimate results.

Polyak,[30] for example, reports the case of a child, 9 years of age, in which the papillomas had been removed repeatedly, and finally by laryngofissure. In fifteen treatments, a "small quantity" of radium was applied to the interior of the larynx for a total of twenty-one hours. The growths disappeared, but recurred four months later. Another series of treatments for a total of eight and one-half hours resulted in a cure. No mention is made of the period of observation nor of the amount of radium and the character of the screen.

Abbe [31] reports the case of a young child, with recurrent papillomas that filled the larynx. Tracheotomy was followed by an extension of the growth to the trachea. "Strong radium" was applied under ether for one-half hour. A second application was made six months later. About one third of the original growth remains below the vocal cord.

Ferreri [20] reports a case of papilloma in a child, 6 years of age. The growths recurred after excision, tracheotomy and laryngostomy. During two months, twenty radium treatments were given. The amount of radium used is not mentioned. The growths disappeared but later recurred; again a series of radium treatments caused them to disappear. They recurred, but removal with a curet then effected a cure. Radium in the hands of an expert is a valuable therapeutic agent. Reports of favorable results, however, without data as to the dosage and the precautions taken to prevent a burn, encourage those who have had no experience with radium to employ it in their cases. This will inevitably lead to many serious complications and fatalities.

METHODS USED BY THE AUTHORS

The treatment of papilloma of the larynx in children is so unsatisfactory that a detailed report of the various methods of treatment employed in our cases is justifiable in order to point out the mistakes and successes.

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29. Plum, A.: Les papillomes du larynx chez l'enfant, Acta oto-laryn. **2**:119-143, 1920.

30. Polyak: Radium bei Papillom, Verhandl. d. internat. Laryngo-Rhinol.-Kong., Berlin, 1911.

31. Abbe, Robert: Papilloma of the Vocal Cords, St. Luke's Hosp. M. & S. Rep., New York **3**:22-24, 1911.

We have tried external operations on the larynx with subsequent skin graft of the interior of the larynx in two cases. This cured the papillomatous condition but left a permanent laryngeal stricture. We have tried repeated endolaryngeal extirpations of the growths; but they always recurred, and usually in increased numbers. Fulguration of the growths, under chloroform anesthesia and through a direct laryngoscope, resulted in temporary benefit or no improvement. Extirpation of the growths and fulguration of their points of attachment was of no value.

Finally, radium alone, or in combination with various of the methods outlined above, was tried in seven of our cases. It is of vital importance to determine the exact amount of radium that should be employed and the interval between the applications that will give the best therapeutic results. We have radiated too heavily in some of our cases. In one case death was due to a tracheo-esophageal burn. In other cases, the radiations were probably not sufficient to produce the best result.

It is possible that the growths in some persons are less sensitive to radium than they are in others; if so the difference cannot be recognized by any variation in the gross or microscopic appearance of the papillomas.

The ideal treatment for papilloma of the larynx in children is one that will restore the voice and cause the growths to disappear rapidly and permanently, with no danger of a complicating pneumonia or an ultimate laryngeal stricture. Our experience encourages us to believe that radium, properly administered, may bring about this result. It is probable, however, that even an ideal therapy will not eliminate the preliminary tracheotomy, because so many of these cases in children are not recognized until complete aphonia or alarming symptoms of respiratory obstruction bring them to the physician.

In this connection, it should be emphasized again that the method of tracheotomy employed in children is of the greatest practical importance and must be observed in order to obtain uniformly good end-results.

REPORT OF CASES

CASE 1 (Surg. No. 29853, 30275, 34290).—A boy, white, aged 2 years, was brought to the hospital, May 13, 1912, with urgent dyspnea. The difficulty in breathing began two months before admission and rapidly became worse. He had had measles at 1 year of age, but otherwise, no illness of any kind. It was noted soon after birth, that the cry was hoarse. The hoarseness had gradually increased, and for several weeks he had been unable to speak above a whisper. The condition on admission necessitated an emergency tracheotomy.

May 19, 28 and June 2: On each of these dates, the child was anesthetized with chloroform, and the growths were fulgurated under direct vision. These treatments had no appreciable effect.

May 30: The tonsils and adenoids were removed. They were much hypertrophied, and we wished to remove all sources of irritation to the larynx.

July 26: The papillomatous masses seemed to have increased in size and number as a result of the previous treatments. Under ether anesthesia, the larynx was opened externally and the papillomas removed, together with all the mucous membrane from which they arose. The denuded area was then cauterized with a hot iron.

This one operation cured the papillomatous condition; but for the last nine years, we have been trying to reestablish the lumen of the larynx. The scar tissue was first dissected out with aid of the Killian suspension apparatus and an attempt was made to maintain and dilate the lumen with intubation tubes. This was a very tedious procedure, for even with strings attached at each end, the tubes were kept in place with difficulty. Inability to swallow food without contaminating the wound was a trying complication, and much of the time nasal feedings were necessary.

Later, a second external operation was necessary. The scar tissue was removed and a Thiersch graft applied to the interior of the larynx. An intubation tube wrapped in iodoform gauze was left in the larynx in order to hold the graft in place. In spite of nasal feedings and frequent dressings, the wound became infected and the intubation tube was removed after four days. A two-way silver tracheal tube was then inserted and worn most of the time for three months. This also necessitated nasal feedings for two weeks; but after that, the child had no trouble in swallowing liquid or solid food. Luckily, no respiratory infection occurred during this period.

At present (August, 1921), the child still wears a tracheal tube. He can speak only in a hoarse whisper; can breathe through his mouth with the tube closed, but cannot exercise with the tube closed. His general health is excellent. He has developed normally and has had no illness of any kind during the nine years he has been wearing the tube.

SUMMARY OF TREATMENT

1. Emergency tracheotomy was performed under local anesthesia.

2. Fulguration: Three treatments under general anesthesia were given with no benefit.

3. Tonsils and adenoids were removed.

4. Laryngofissure was performed with excision of the papillomas, together with all the mucous membrane from which they arose. Cauterization of the denuded area with the actual cautery.

5. This procedure cured the papillomas but resulted in a stricture of the larynx, which subsequent treatment has failed to cure.

6. The patient has been under observation for nine years.

CASE 2 (Surg. No. 30499).—A colored boy, aged 3 years and 9 months, was admitted to the hospital, Sept. 6, 1912, with marked inspiratory and expiratory dyspnea and complete aphonia. The difficulty in breathing was first noticed when the child was 8 months old. For several weeks, he had had severe attacks of dyspnea; these usually occurred at night and were associated with profuse sweating. No history was obtained of any of the acute infectious diseases.

The general physical examination was negative, with the exception of a large umbilical hernia. There was no evidence of tuberculosis or syphilis.

The tonsils and adenoids were removed four months before admission, with the idea that the difficulty in breathing was due to hypertrophied adenoids.

A low tracheotomy was performed under local anesthesia on the day of admission. Laryngeal examination showed the entire glottis filled with growth. The larynx was opened ten days later, and the entire glottis and subglottic area as far as the ring of the cricoid was found thickly studded with papillomatous growths. All the involved mucous membrane was removed in one piece and a large Thiersch graft applied to the denuded area. The graft was held in place with gauze wrapped in protective. The wound was left open. In this case, also, nasal feedings were necessary; but it is our impression that the entire graft was lost as a result of infection due to contamination of the wound with saliva and vomitus.

The external wound closed by granulation within three weeks. Dilatations were attempted, but were soon abandoned owing to lack of cooperation by the parents.

At present (August, 1921), the child has a complete stricture of the larynx, but is otherwise well.

SUMMARY OF TREATMENT

1. Tracheotomy was performed under local anesthesia.

2. Laryngofissure, with removal of all involved mucous membrane was performed, and a Thiersch graft applied.

3. The graft was probably lost owing to infection. Permanent stricture of the larynx resulted.

CASE 3 (Surg. No. 37713).—A white boy, aged 4 years, was admitted, March 14, 1914. He had always been "sickly." He did not cry until he was 2 months of age. He began to talk at 11 months, but the voice was never clear. There was a history of measles at 11 months of age. One year ago he had an acute respiratory infection, and since that time, the voice had become progressively worse. During the last three weeks, he had had a rise of temperature from 99.6 to 104 F.; the voice was much worse; he had had attacks of dyspnea, and was rapidly losing weight.

On admission, the child was given antitoxin, although no definite evidences of diphtheria were ever discovered. The physical examination and the roentgen-ray examination of the chest were both negative. Examination of the blood revealed 9,800 leukocytes. The Wassermann reaction was negative, but the skin tuberculin test was strongly positive.

Examination of the larynx disclosed two or three small papillomas sharply localized in the anterior commissure.

March 18: Papillomas removed with the aid of a Jackson laryngoscope; tracheotomy seemed unnecessary.

April 7: Papilloma again removed. They were still sharply localized in the anterior commissure. Patient allowed to go home.

Aug. 21, 1915: For the last few months, the former symptoms have gradually recurred. Emergency tracheotomy was necessary today on account of the sudden onset of severe dyspnea with cyanosis; the entire larynx apparently filled with growth.

August 26, September 2 and 16: On each of these dates, the child was given chloroform and the growths fulgurated. On the latter date, all papillomas were removed and their bases fulgurated.

September 23: The growths have recurred and again fill the entire larynx. Radium,[32] 103 mg., enclosed in a soft rubber catheter was placed in the larynx and left for one hour.

October 9: Radium, 103 mg., held between cords for one and one-half hours.

October 11: The growths had decreased to such an extent that the patient could breathe normally through the mouth; tracheotomy tube removed.

October 26: Patient discharged; tracheal wound closed; voice strong but husky.

The patient had pneumonia in January, 1916, at home. Following this, the voice became worse and the attacks of dyspnea returned.

March 16, 1916: Tracheal tube again inserted. The larynx was again filled with growth.

April 1: Tonsils and adenoids removed, indications being: (1) frequent attacks of tonsillitis; (2) enlarged cervical glands, and (3) positive tuberculin test.

April 12: Radium, 103 mg., intralaryngeally for forty-five minutes.

April 21: Radium, 103 mg., intralaryngeally for fifteen minutes.

May 3: Radium, 103 mg., intralaryngeally for forty-five minutes.

The growths have almost disappeared. The vocal cords can now be seen.

May 8: Tracheal tube removed and wound allowed to close; breathed normally through the mouth and the voice was much improved.

May 10: Mother took child home to West Virginia today, although urged to leave him here for several weeks longer.

May 20: Letter stated that he was rapidly becoming worse. A few days later the child died on the train while on his return to Baltimore. The larynx was opened by the family physician and the entire subglottic space as far as the first ring of the trachea was found to be filled with growth.

SUMMARY OF TREATMENT

1. Excision of papillomas by intralaryngeal methods. They recurred and were removed again three weeks later. Tracheotomy was not necessary at this time.

2. Patient had very little trouble for a year. Emergency tracheotomy necessary sixteen months after first operation.

3. Four treatments by fulguration under general anesthesia were given with no benefit.

4. Radium, 103 mg., for one hour and later for one and one-half hours, intralaryngeally, caused all obstructive symptoms rapidly to disappear and the tracheal tube was removed.

5. Symptoms recurred after pneumonia; tracheal tube again inserted six months after its removal.

6. Radium again caused the growths to disappear and the tube was removed. Recurrence was rapid, however, and the child died of asphyxia while on the train.

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32. All intralaryngeal applications of radium mentioned in this paper were screened with 2 mm. of brass and 2 mm. of rubber. In all extralaryngeal treatments, the radium was enclosed in a capsule of brass, 2 mm. in thickness, and a lead box 2 mm. in thickness and one thickness of box-board.

CASE 4 (Surg. No. 36509).—A colored boy, aged 1 year and 9 months, entered the hospital, March 9, 1915, on account of hoarseness of four or five months' duration and difficulty in breathing. He had pertussis at 11 months but no other infectious disease. A tracheotomy was not necessary on admission. The general physical examination was negative, aside from rachitis. The Wassermann and Pirquet tests were negative. There was one large mass of papillomatous growth in the larynx that seemed to arise from the true cord on the right. He had suffocating attacks only when asleep.

March 10: Radium, 500 mg., externally, over the larynx at a distance of one-half inch (12.7 mm.) for six hours.

March 15: The papillomas have not decreased in size.

March 27: Radium, 564 mg., externally, over the larynx at a distance of one-half inch (12.7 mm.) for six and three-quarters hours. This resulted in a second degree burn of the skin under the chin and just above the sternum.

April 17: The growths were much smaller. The true cords could be clearly seen for the first time since admission.

May 13: The voice was much clearer than on admission.

June 10: Laryngeal examination showed that the papillomas were increasing in size and number. The difficulty in breathing was more marked than on admission.

June 26: Tracheotomy was necessary. The growths in the larynx were fulgurated under chloroform. Killian suspension apparatus was used.

July 13: Laryngeal examination showed a marked increase in the number of papillomas.

July 22: Radium was used intralaryngeally, 500 mg., for two and one-half minutes.

August 7: Fulguration was used after removal of large masses of papillomas.

August 27, September 10: Fulguration and Killian suspension apparatus were used, with chloroform anesthesia.

September 25: The laryngeal condition showed no improvement.

September 28: Radium, 103 mg., intralaryngeally, in a metal case covered with a soft rubber catheter, held between cords for forty-five minutes under ether anesthesia.

October 30: Radium treatment, intralaryngeally, attempted; but the larynx was so filled with growth that the radium carrier could not be introduced between the cords.

November 5: Radium, 103 mg., intralaryngeally, for one and one-half hours.

November 20: Radium, 103 mg., intralaryngeally, for two hours.

December 1: The papillomas were much smaller and were pale gray in marked contrast to the former pink color.

December 20: Radium, 103 mg., intralaryngeally, for one hour and fifty-five minutes. Examination showed that all the growths had disappeared with the exception of one small tag on the right cord.

December 23: Tracheotomy tube removed.

December 27: Necessary to replace tracheal tube. Patient had severe coughing attacks when eating.

December 28: When patient attempted to swallow milk, it returned through the tracheal tube; temperature 101.6 F.

December 29: Attempts to feed through nasal tube not successful: the tube always entered the trachea. A septic temperature and an abundant purulent discharge through the tracheal tube continued until death, Feb. 16, 1916.

Necropsy[33] disclosed an extensive ulceration of the interior of the larynx and a tracheo-esophageal fistula at the upper end of the trachea. Several papillomas were found in the right pyriform sinuses. There was an extensive bronchopneumonia and a chronic diffuse thyroiditis.

SUMMARY OF TREATMENT

1. External radiation that resulted in a second degree skin burn and, temporarily, in a marked decrease in the size of the papillomas was used.

2. The growths reappeared in increased numbers and a tracheotomy was necessary.

3. Fulguration was employed on three occasions with no apparent benefit.

4. The papillomas were removed intralaryngeally on one occasion. They rapidly recurred.

5. From September 28 to December 20 he had four intralaryngeal treatments. On each occasion, 103 mg. of radium was used and the total exposure was eight hours and ten minutes.

6. These treatments resulted in an extensive intralaryngeal burn, the formation of a tracheo-esophageal fistula and death from bronchopneumonia.

7. At necropsy, papillomas were still present in the right pyriform sinus.

CASE 5 (Surg. No. 43200).—A colored boy, aged 8 years, was admitted, July 13, 1917, on account of aphonia and "noisy breathing at night." These symptoms appeared after an operation in November, 1916, for removal of tonsils and adenoids. He had always been a mouth-breather. He had had measles when 7 years of age (so this disease might have been an etiologic factor).

Laryngeal examination showed a large mass of papillomas; but they involved only the anterior half of the true cords.

Under ether anesthesia, these growths were removed without injury to the surrounding mucous membrane. Tracheotomy was not necessary.

We have been unable to trace this patient, and so the result is doubtful.

CASE 6 (Surg. No. 44334).—A white boy, aged 4 years, was admitted, May 25, 1917. The symptoms, hoarseness and difficulty in breathing, began without any apparent cause, when the child was 3 years of age. He had never had an acute illness of any kind. The general physical examination was negative aside from the laryngeal condition.

May 25: Papilloma excised, using a Jackson laryngoscope. There was free breathing for seven weeks.

August 25: Papillomas had recurred; again excised.

December 11: Papillomas had returned; low tracheotomy performed under local anesthesia and primary chloroform.

December 13. Radium, 500 mc., intralaryngeally, for five minutes.

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33. For a full report of the necropsy, refer to article by Duffy, W. C.: Johns Hopkins Hosp. Rep. **18**:417-438, 1919.

Jan. 3, 1918: Radium, 600 mc., intralaryngeally, for one and three-quarters minutes.

January 19: Radium, 542 mc., intralaryngeally, for three and one-half minutes; no change in the size or number of the growths.

February 9: Radium, 1,065 mc., intralaryngeally, for three minutes. Radium apparently had no effect on the growths in the larynx.

March 2: Excision of papillomas through mouth.

March 13: Radium, 1,118 mg., direct to throat externally—three areas—twenty minutes each.

May 27: Radium, 926 mg., in lead box on 1 inch (2.54 cm.) gauze applied to larynx—two areas—one-half hour each.

June 15: Complete aphonia; papillomas have recurred; again excised. Radium, 1 gm., externally, in front and on each side of larynx for thirty minutes; lead 3 mm. in thickness interposed; distance one-half inch (12.7 mm.); total exposure one and one-half hours.

July 10: Radium, 584 mg., in lead tube with three-fourths inch (19.05 mm.) gauze applied to larynx—three areas—twenty minutes each.

August 7: Radium, 150 mg., applied to neck at three-fourths inch (19.05 mm.) distance for one hour.

August 28: Radium, 150 mg., three-fourths inch (19.05 mm.) distance, applied to larynx—three areas—one-half hour each.

September 25: Radium, 150 mg., at three-fourths inch (19.05 mm.), applied to larynx for one-half hour.

October 31: Radium, 1,535 mg., at one-eighth inch (3.17 mm.), applied to three areas on neck for fifteen minutes.

November 20: Radium, 700 mg., *in a tube with open end,* placed directly on papillomas for five minutes. A profuse purulent bloody discharge is coughed out of the tracheal tube. Larynx contains perhaps more papillomas than on admission.

Jan. 23, 1919: Papillomas in trachea both above and below the tracheal tube. These were removed under local anesthesia.

February 10: Radium, 879 mc., applied through tracheal opening directly to growths in larynx and trachea for ten minutes.

November 21: Entire larynx filled with growth. Radium, 700 mc., applied directly to growth *in an open-end tube* for ten minutes.

Jan. 20, 1920: Excision of papillomas from larynx and trachea. One large pedunculated mass at lower end of tracheal tube almost completely occluded the trachea.

June 12: Voice slightly improved; still difficulty in breathing owing to growth in the trachea; large pedunculated masses again excised from trachea above and below the tube.

June 8, 1921: Examination under ether; marked improvement—only one pedunculated growth seen in glottis. This was attached to the left vocal cord. It was removed. No evidence of any recurrence seen in trachea; general health excellent; wears tube constantly though often closed with a cork; voice much improved; goes to the public school and plays baseball and other games without difficulty; has had whooping cough and measles without complication since the tracheotomy tube was introduced in December, 1917.

CASE 7 (Surg. No. 43522).—A Jewish child, aged 3 years, was admitted, Aug. 15, 1917, with profound respiratory distress of six days' duration, marked cyanosis and complete aphonia. It had always been sickly, having had a

severe attack of tonsillitis, acute cervical adenitis and double otitis media in December, 1915. The adenoids were removed after this attack. It had had chickenpox in December, 1916, and the voice had been hoarse since that time. It had had measles in May, 1917.

August 21: Tracheotomy; laryngeal examination showed the entire glottis filled with growth.

August 25: Excision of papillomas with the aid of a Jackson laryngoscope; ether anesthesia.

August 30: The growths rapidly recurred; again excised.

December 8: Radium, 510 mc., for two and one-half minutes intralaryngeally.

December 29: Radium, 695 mc., for two minutes intralaryngeally. Laryngeal examination showed that the growths were paler but there was no evident decrease in size.

Jan. 9, 1918: Radium, 542 mc., for four minutes intralaryngeally.

April 13: Radium externally, 1 gm., over the front and each side of the larynx at a distance of one-half inch (12.7 mm.) for twenty minutes; lead filter 3 mm. in thickness; total exposure one hour.

May 7: No improvement; laryngeal examination showed large masses of growth on both aryteno-epiglottic folds, both true cords and in the subglottic region. When the tracheal tube was removed papillomatous masses immediately filled the opening. Further operative treatment not advisable.

October 16: The child died of pneumonia during the influenza epidemic of 1918. Necropsy was not permitted.

CASE 8 (Surg. No. 44329).—A white boy, aged 3½ years, was admitted, Nov. 28, 1917. Hoarseness had begun six months previously. For three months he had had aphonia and gradually increasing dyspnea. He had had none of the acute infectious diseases. His health had been excellent up to onset of present trouble.

November 28: An emergency tracheotomy was necessary on admission. On direct examination of the larynx, no normal landmarks were seen; large pink masses of papillomas filled the entire glottis.

December 8: Radium, 510 mc., intralaryngeally, for two and one-half minutes.

December 29: Radium, 695 mc., intralaryngeally, for two minutes. Laryngeal examination showed the papillomas were paler in color but not appreciably diminished in size or number.

Jan. 19, 1918: Radium, 542 mc., intralaryngeally, for four minutes. There was still no evident change in the size or number of the growths in the larynx.

February 12: Parents refused permission for further intralaryngeal radium treatments. Under chloroform anesthesia all papillomas were removed by intralaryngeal methods.

February 23: Radium, 1 gm., externally, at a distance of one-half inch (12.7 mm.) to each side of the larynx for one hour.

February 26: Tracheal tube had been tightly corked for a week; the tube removed and tracheal opening allowed to close.

February 28: Discharged; voice hoarse but much better than on admission; had no difficulty in breathing.

April 19: Letter: "Has had no trouble with breathing. Voice is steadily improving."

April 4, 1921: Letter: There has been no evidence of recurrence of the papillomas. The voice is still husky. His general health is not good, appetite poor; has a chronic dry cough; is under-weight and undersize; averages only three days a week at school.

CASE 9 (Surg. No. 45463).—A white boy, aged 4½ years, was admitted, April 29, 1918. He had been a normal, healthy baby. He had had "tracheitis" at 7 months, otherwise no illness of any kind. Hoarseness was first noticed when he was 2½ years old. Examination of the larynx at this time was reported as negative. The voice gradually became worse, and in January, 1917, an examination revealed papillomas on the true cords. These were removed. In April, 1917, it was necessary to perform a tracheotomy on account of the increasing dyspnea. The Wassermann reaction at that time was said to have been positive; he was given mercury and iodids. The parents were not examined. When we first saw him in April, 1918, the Wassermann reaction was negative. There were no stigmas of congenital syphilis, and the papillomas excised at this time showed no histologic evidence of syphilis.

April 30: Removal of growths from larynx through a Jackson laryngoscope.

May 8: Radium, 904 mg., externally on each side of larynx for one-half hour; lead, 2 mm. thick; distance, three-fourths inch (19.05 mm.); total exposure one hour.

June 19: Radium, 1 gm., externally on each side of larynx for forty minutes; distance 1 inch (2.54 cm.).

May 13, 1921: Letter from Dr. John A. Whittle of Rochester, N. Y., saying, "General condition much improved. Still wears the tracheal tube, but can breathe with difficulty with the opening closed. Cannot speak above a whisper. On the advice of Dr. D. R. Ingersoll has had three or four roentgen-ray treatments during the last year."

August 17: Another letter from Dr. Whittle states that the child died, Aug. 6, 1921. For several weeks before death, he had symptoms suggesting a pulmonary abscess. Necropsy refused.

CASE 10 (Surg. No. 48331).—The papillomas in this case were possibly different from those in the preceding cases, although microscopically no difference was apparent.

A white boy, aged 2 years, was admitted, May 17, 1919. There was no illness previous to onset of present trouble in March, 1919. At that time he was said to have had laryngeal diphtheria, although the only symptoms were difficulty in breathing. The voice was never hoarse. It was necessary to intubate him three times during the first week and several times during the following week because the tube was coughed out.

On admission, he had extreme dyspnea. Leukocytes numbered 15,000; culture from throat and larynx was negative.

May 18: Tracheotomy under local anesthesia; large mass of papillomas below cords; small piece removed. This was followed by pneumonia, with fever, leukocytosis, râles and dulness over the left side of the chest.

June 10: Entirely recovered from the pneumonia; larynx condition unchanged; no local treatment.

October 25: Larynx examined under general anesthesia; growths had entirely disappeared, but there was a partial paralysis of the left vocal cord.

June 6, 1920: Still wore tube; but it was closed with a cork much of the time; general health good; no growths to be seen in the larynx; still weakness of the left cord.

November 15: Tracheal tube removed and opening allowed to close.

August 22: Well.

CASE 11 (General No. 147459).—A white boy, aged 19 months, was admitted, March 9, 1921, with extreme dyspnea. There had been a history of respiratory difficulty since the child was 2 months of age; this gradually increased with occasional exacerbations. The dyspnea had been much worse during the last four months.

There was no history of any of the infectious diseases. The dyspnea was both inspiratory and expiratory; temperature was 99.4 F.; the lungs were clear. The skin tuberculin test was negative. There was no evidence of diphtheria.

March 10: Tracheotomy under local anesthesia.

March 17: Examination of the larynx under ether anesthesia showed large masses of papillomas on both vocal cords, but most abundant in the anterior commissure. The largest masses were removed. Radium, 850 mc., for ten minutes, intralaryngeally.

April 9: Sudden rise of temperature to 105 F. with cyanosis. Tube changed with no relief. Smears made from the tube showed Klebs-Löffler bacilli; 6,000 units of antitoxin given.

June 3: All acute symptoms disappeared within a few days after the antitoxin was given; but there was still a positive tube culture.

June 23: Smears from the tube were negative for the first time since April 9.

August 9: Papillomas had recurred in increased numbers. Under general anesthesia, all the largest tumors were removed by direct laryngoscopy. Radium, 994 mg., for eight minutes intralaryngeally.

September 7: Again a sudden elevation of temperature to 102 F., but without respiratory distress. Culture negative for diphtheria, but 5,000 units of antitoxin was given intramuscularly as a precautionary measure.

September 11: Temperature normal; general condition good. Is still in the hospital.

STUDIES IN EXPERIMENTAL TRAUMATIC SHOCK

V. THE CRITICAL LEVEL IN A FALLING BLOOD PRESSURE*

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Gesell has distinguished between the *initiating* and the *sustaining* factors in shock. The previous paper of this series[1] was concerned with evidence for a toxic agent developed in damaged tissue and acting as an initiating factor in the onset of shock. The present paper is concerned with a sustaining factor—low blood pressure.

The low blood pressure in both experimental and clinical shock is explained by a diminution of blood volume, an actual decrease in the amount of fluid which is kept circulating. In the early stages of secondary shock, however, the diminished volume may not be associated with a reduced arterial pressure. The only way in which the pressure can be maintained in the presence of a smaller amount of circulating fluid is by a lessening of the capacity of the circulatory system. This diminished capacity is the consequence of extra activity of the vasoconstrictor center causing greater contraction of peripheral vessels. When the blood pressure begins to fall, there may also be passive contraction of these vessels because they are no longer distended by the internal pressure which normally prevails. With further development of shock, there is a fall of arterial pressure below the limits of normal variation, a fall which is accounted for by reduction of the blood volume below the minimal capacity of the system and by a final relaxation of vascular tone as the vasomotor system becomes less active.

The effects of the changes above outlined are fundamentally important to an understanding of the sequence of events in shock. In order to comprehend their significance, it is necessary to refer to the principles of the circulation. We must keep in mind the fact that the blood circulates in order to supply with food and oxygen the tissues which are remote from the alimentary tract and the lungs, and to carry waste from the tissues to surfaces where it may be excreted. The interchange between the flowing stream and the active tissues occurs in the *capillary* portion of the circulatory system. This is the essential region. All other parts of the circulation—heart, arteries and veins—exist in order to provide a continuous flow of blood through the capil-

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* From the Laboratory of Physiology of the Harvard Medical School.

1. Cannon, W. B.: Studies in Experimental Traumatic Shock, Arch. Surg. 4:1 (Jan.) 1921.

laries. The high head of pressure normally maintained in the arteries serves, first, to keep a constant flow passing through the capillaries in all parts of the body no matter what extra demands are placed on the general supply of blood by organs which, becoming active, have dilated vessels. Secondly, this high head of pressure assures speed in the passage of blood from the heart back to the heart again. And since the function of the blood as a common carrier depends on the number of trips which it makes from places where it is loaded to where it is unloaded, the speed of the circulation is evidently an important determinant of the capacity of the blood for service in the body.

THE EFFECTS OF DECREASED BLOOD VOLUME

With a decreased volume of blood, the blood pressure may still remain at its normal level because of compensatory vasoconstriction. One might suppose from the restored blood pressure that the blood supply to all parts of the organism is occurring at its normal rate. The admirable investigations of Gesell [2] have shown, however, that this is far from being the case. The vasoconstriction which takes place when, in consequence of hemorrhage or tissue injury, the blood volume is reduced, is not uniform throughout the vascular distribution. Gesell's observations prove that under such circumstances the volume-flow through the submaxillary gland, for example, is greatly diminished. In one instance, a removal of 10 per cent. of the estimated blood volume of the animal caused a reduction of the volume-flow per minute through this gland amounting to 60 per cent. of the basal flow (i.e., the amount passing through the gland when at rest). This occurred even though there was no fall of arterial pressure. The volume-flow is obviously of the utmost importance in the delivery of oxygen to the tissues, for each red blood corpuscle is a carrier. If the number of carriers is reduced to this great degree as a consequence of slight hemorrhage or slight reduction of blood volume, it is obvious that the tissues are in danger of an insufficient supply.

It should not be supposed that all parts of the body are affected in the same way as the submaxillary gland when vasoconstriction compensates for diminished volume. There is good evidence [3] that in the presence of normal arterial pressure the blood vessels of the central nervous system and the heart do not undergo contraction. The effect, therefore, of a peripheral constriction which would shut down the volume-flow in peripheral structures would serve to maintain an adequate volume-flow in the essential organs.

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2. Gesell, R.: Am. J. Physiol. **47**:502 (Jan.) 1919.

3. Wiggers, C. J.: Modern Aspects of the Circulation in Health and Disease, New York, Lea and Febiger, 1915, pp. 83, 84.

THE EFFECTS OF DECREASED ARTERIAL PRESSURE

Gesell's studies prove that the volume-flow to peripheral organs is more diminished by reduction of blood volume than by reduction of blood pressure. When blood pressure begins to fall, however, the force which is driving the blood through the capillaries begins to become less effective, consequently the rate of flow will, as a rule, steadily diminish as the pressure falls. Thus the volume-flow not only to peripheral structures but also to the essential organs, such as the central nervous system and the heart, becomes gradually less and less.

Diminished blood volume, therefore, results in a lessened blood supply to peripheral tissues because of a primary vasoconstriction; and lessened blood pressure results in diminished blood supply both to peripheral tissues and to central organs because of a slower flow. All parts of the body may then begin to suffer from disturbances of the circulation, initiated by diminished volume of blood and continued as the volume becomes less and less.

The materials delivered to the tissues by the flowing blood may be classified into food, water and oxygen. The degree of dependence of cells on these materials varies with the materials and also with different groups of cells. Thus there may be prolonged absence of fresh food supply in the blood without disturbance of function. A less prolonged absence of fresh water supply in the circulating stream is also endured without serious damage. The need for oxygen, however, is quite different from the need for either food or water. It is urgently necessary that oxygen be continuously delivered if tissues are to be kept active. It becomes a matter of importance, therefore, to inquire into the evidence that there actually is an insufficient oxygen supply delivered to the tissues when the flow of blood through the capillaries is much reduced.

RELATION OF REDUCED ALKALI RESERVE TO BLOOD PRESSURE

In 1910, Henderson[4] pointed out that in the absence of an adequate supply of oxygen the development of acid substances in the tissues might be expected, in consequence of the partial asphyxia. Later, Crile[5] and his co-workers reported results which indicated that a condition of "acidosis" is present in various clinical states, including shock. And in 1917, during a study of the toxemia of gas gangrene, Wright[6] observed a reduction of the alkalinity of the blood serum as determined by titration with acid to a certain end point. Patients suffering from gas gangrene have many of the symptoms of shock, and Wright argued

4. Henderson, Yandell: Am. J. Physiol. **27**:167, 174, 1910.

5. Crile, G. W.: The Origin and Nature of Emotions, Philadelphia, W. B. Saunders Company, 1915, p. 227.

6. Wright, A. E.: Lancet **1**:8 (Jan. 6) 1917.

that the "acidemia," as he called it, of this condition was the cause of these symptoms.

During the summer of 1917, at Béthune, one of us (W.B.C.) made use of the then newly described method and apparatus introduced by Van Slyke,[7] and obtained estimates of the sodium bicarbonate, or alkali reserve of the blood plasma in wounded men suffering from the low arterial pressure which accompanies shock, hemorrhage and gas gangrene.[8] The results given by the Van Slyke instrument are expressed in percentage by volume of carbon dioxid which can be separated from the plasma after it has been exposed to an atmosphere containing 5.5 per cent. of the gas (the concentration existing in the pulmonary alveoli and present in the final air of an extreme expiration). Any figures lower than 50 per cent. by volume of carbon dioxid in the plasma of adults indicates a reduction of the alkali reserve below the normal range of variation. In the sense defined by L. J. Henderson[9] and by Van Slyke and Cullen,[10] readings below this normal range may be regarded as marking a condition of "acidosis." The expressions "reduction of the alkali reserve" and "reduction of the carbon dioxid capacity" may be used interchangeably with the reduction of blood alkali. In the Béthune cases, observations were made on the relation of reduced alkali reserve to blood pressure, to pulse, and respiration, and to other attendant conditions.

In forty-five different coincident determinations of blood pressure and carbon dioxid capacity, a rough relation between the two was found; in general, the lower the blood pressure, the lower the alkali reserve. This relation is illustrated in Table 1.

TABLE 1.—Relation Between Blood Pressure and Carbon Dioxid Capacity

No. of Cases	Carbon Dioxid Capacity Percentage by Volume	Systolic Arterial Pressure in Millimeters of Mercury
6	50 to 59 (av. 53)	90
25	40 to 49 (av. 44)	75
8	30 to 39 (av. 35)	72
6	20 to 29 (av. 24)	50

It is noteworthy that in thirty-nine of the forty-five cases, the average systolic pressure was 75 millimeters of mercury, or less, and that in all these there was a carbon dioxid capacity of less than 50 per cent. by volume, i.e., below the normal range. Furthermore, as the average carbon dioxid capacity was low, the average systolic pressure

7. Van Slyke, D. D.: J. Biol. Chem. **30**:347 (June) 1917.

8. Cannon, W. B.: Acidosis in Shock, Hemorrhage and Gas Infection, J. A. M. A. **70**:531 (Feb. 23) 1918.

9. Henderson, L. J.: Science, **37**:389, 1913.

10. Van Slyke, D. D., and Cullen, G. E.: J. Biol. Chem. **30**:292 (June) 1917.

was likewise low. In the cases mentioned above, some process had been going on for hours, often six or eight, that had brought about the state observed on admission of the patient. The progressive character of the process was shown in one instance in which the carbon dioxid capacity one hour after the wounding was 50 per cent., and five hours later, with no corrective treatment, it had fallen to 40 per cent. The condition has a gradual rather than an acute onset.

EXPLANATION OF THE DIMINISHED ALKALI RESERVE

Two explanations have been offered to account for the reduction of the bicarbonate of blood plasma: one that nonrespirable acid, such as lactic acid, develops in the tissues because of oxygen want, and, uniting with the sodium of sodium bicarbonate, drives off carbon dioxid, which is breathed out; the other that excessive respiration diminishes the carbonic acid in the blood with consequent *alkalosis*, and that thereupon the extra alkali disappears into the tissues, or diffuses into body fluids outside the blood, or escapes through the kidneys. The former process has been designated by Henderson as the "acidotic," the latter as the "acapnial" reduction of blood alkali.

There is a good deal of evidence that an insufficient oxygen supply to the tissues results in formation of lactic acid. Zillesson,[11] 1891, noted that when the blood supply of the muscles or liver was limited, lactic acid was formed in these organs. Araki[12] proved that lactic acid (lactates) were present in the urine of dogs and rabbits in conditions of oxygen lack brought about by breathing carbon monoxid or by a low percentage of oxygen in the inspired air. In an artificially produced anemia, Irisawa[13] found that the lactic acid content of the blood increased as the oxygen lack became more severe. More recently, Milroy[14] and Penfield[15] have reported that reduction of blood alkali appears typically after a severe hemorrhage. And within the last few years, a number of workers have published papers on experimental shock in which there is agreement that a decreasing alkali reserve is associated with a falling blood pressure (McEllroy,[16] Guthrie,[17] Erlanger and Gasser[18] and Gesell[19]). The low blood pressure in the late stages

11. Zillesson: Ztschr. f. physiol. Chem. **15**:404, 1891.
12. Araki: Ztschr. f. physiol. chem. **19**:447, 1894.
13. Irisawa: Ztschr. f. physiol. chem. **17**:340, 1893.
14. Milroy: J. Physiol. **51**:272, 1897.
15. Penfield, W. G.: Am. J. Physiol. **48**:121 (Feb.) 1919.
16. McEllroy, W. S.: Acidosis in Shock, J. A. M. A. **70**:847 (March 23) 1918.
17. Guthrie: Am. J. Physiol. **45**:544, 1918.
18. Erlanger, J., and Gasser, H. S.: Am. J. Physiol. **50**:116 (June) 1919.
19. Gesell, R.: Am. J. Physiol. **47**:459 (Jan.) 1919.

of experimental shock, according to Macleod,[20] is associated with a demonstrable increase of lactic acid in the blood—an effect attributed by him to anoxemia because of depression of both the respiratory and the circulatory functions. All the conditions described above, which are associated with an increase of lactic acid or a reduced alkali reserve, are characterized by diminished blood volume, or diminished blood pressure, or decreased carrying power of the corpuscles, so that the delivery of oxygen to the tissues is reduced. It is well proved that in the absence of adequate oxygen supply the lactic acid which accompanies muscular contraction, for example, is not burned to carbon dioxid and water.[21] The liberation of such acid would produce the effects which have been observed—a demonstrable increase of lactates in the blood, and a diminution of sodium bicarbonate. It may be, as Wertheimer, Fabre and Clogne[22] have noted, that diacetic acid is present in some instances.

The other explanation for the reduced blood alkali attributes the change to relative increase of pulmonary ventilation. Henderson and Haggard[23] have reported that if they permit an animal to breathe to excess, as it naturally does during the development of shock from trauma of the abdominal viscera, failure of the circulation and death are induced. This is associated with a lowering of both the carbon dioxid content and the carbon dioxid capacity of the blood and also a lowering of the arterial pressure. In explanation of these results, Henderson and Haggard[24] have found that when animals are subjected to progressively decreasing oxygen percentages, the first effect is an abnormally large loss of carbon dioxid from the body due to excessive breathing and that thereafter alkali passes out of the blood to compensate for the alkalosis thus developed. In other words, when the carbonic acid of the blood is lowered, sodium bicarbonate also falls. A modification of this view has been suggested by Moore,[25] who assumes that as a consequence of shock there is a general lowering of metabolic activity to about one-third the normal rate. If then the lungs continue functioning at their usual rate, or even less, there will be removed from the blood an excess of carbon dioxid over that which is produced, and the blood will be altered in the alkaline direction.

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20. Macleod, J. J. R.: Am. J. Physiol. **55**:190 (March) 1921.

21. Fletcher and Hopkins: J. Physiol. **35**:298, 1907.

22. Wertheimer, Fabre and Clogne: Bull. et mém. Soc. de chir. **45**:9, 1919.

23. Henderson, Yandell, and Haggard, H. W.: J. Biol. Chem. **33**:371 (Feb.) 1918.

24. Henderson, Yandell, and Haggard, H. W.: J. Biol. Chem. **43**:3 (Aug.) 1920.

25. Moore, B.: Lancet, **2**:474 (Sept. 13) 1919.

Thereupon, the kidneys and tissue cells remove alkali from the circulation; and if the blood is examined for circulating sodium bicarbonate, a lower figure than the normal is obtained.

With reference to the argument in the foregoing explanations, we may admit at once that excessive breathing due to oxygen want may have the effect which Henderson has reported. Further, we may admit that in the presence of an excess of alkali, the tendency of the tissues, and of the kidneys, in case there is sufficient blood pressure to permit them to act effectively, would be to remove the excess from the blood stream. There is some question, however, whether the hyperpnea assumed by Henderson, or the continued normal breathing in the absence of adequate stimulation (i.e., the normal carbonic acid content of arterial blood), assumed by Moore, are actually present in cases of shock in human beings. Certainly the method of inducing excessive respiration in experimental shock which Henderson employed, that of positive overventilation of the lungs or vigorous manipulation of the diaphragm, does not represent the conditions attending the onset of

TABLE 2.—Relation of Carbon Dioxid Capacity to Respiration

No. of Cases	Carbon Dioxid Capacity	Average Respiratory Rate
17	40 to 49 (av. 44)	24
7	30 to 39 (av. 35)	28
6	20 to 29 (av. 24)	44

shock as seen in man. The classic descriptions of shock refer to respiration as being shallow and feeble, interrupted by occasional sighs. Such was the character of the breathing noted in numerous cases of shock at Béthune. The rate, as shown in Table 2, is likely to be much more rapid than normal; but since the breathing is shallow, the result is not likely to be an effective ventilation of the lungs.[26] In three cases of shock in man observed by Aub, the ventilation per minute ranged between 5.77 and 7.19 liters. In three other wounded men with normal blood pressures, the average figure was 8.2 with a range of from 6.81 to 9.59 liters per minute. It is unfortunate that it was impossible to obtain more evidence regarding the volume of ventilation in shock observed in human beings. If respiration is shallow, however, it seems probable that there would be no reduction or relatively slight reduction of the alveolar carbon dioxid, and a consequent lessening of the concentration of carbon dioxid in the blood. According to Henderson and Haggard,[27] morphin, by depressing respiration, tends to cause accumulation of carbonic acid in the blood, and therefore prevents the lowering of the

26. Edsall: Boston M. & S. J. **167**:647, 1912.

27. Henderson, Yandell, and Haggard, H. W.: J. Biol. Chem. **33**:344 (Feb.) 1918.

alkali reserve. In the cases of human shock, as observed in Béthune, morphin was given as a routine procedure shortly after the men were wounded. In Table 3 are presented figures showing the systolic and diastolic blood pressures, the carbon dioxid capacity and the morphin dosage in eleven typical cases. These figures demonstrate that prompt administration of morphin, even in doses of one-half grain (0.0324 gm.) may not prevent a reduction of the alkali reserve.

Besides doubt as to whether excessive respiration is present in human shock, there is further question whether it would have, if present, a causal relation to the onset of the shock state. Aub [28] found that the volume of respiration per minute, in experimental shock produced by muscle injury, increased in ten experiments 54 per cent. above the average for the controls. This was, however, before the onset of shock. When the condition of shock became established, the increase

TABLE 3.—Systolic and Diastolic Blood Pressures, the Carbon Dioxid Capacity and the Morphin Dosage in Eleven Typical Cases

Blood Pressure		Carbon Dioxid Capacity	Morphin Dosage, Grain
Systolic	Diastolic		
92	70	49	¼
79	56	30	½
64	40	21	½
76	46	41	¼
42	28	40	¼
72	48	38	½
80	58	43	¼
56	20	26	¼
92	62	47	¼
68	42	36	½
75	46	36	¼

was only 14 per cent. above the controls. One might assume that this indicated that the increased volume of respiration was causally related to the development of low blood pressure. Aub repeatedly observed, however, a rapid breathing with a large increase of the ventilation rate per minute under urethane anesthesia without the onset of shock. Furthermore, uniform artificial respiration may be given to an animal while passing into the state of shock, and under these circumstances no diminution of the carbon dioxid capacity of the plasma occurs until the blood pressure falls. Thus, the respiratory factor is not permitted to vary, and the excessive respiration, as postulated by Henderson, is not capable of producing the changes which he regards as the consequence of hyperpnea. Nevertheless, a low pressure develops, and as the pressure continues to fall, there is a reduction of the alkali reserve. In one such instance, the blood pressure fell in half an hour from 110 to 40 millimeters of mercury with a decline in carbon dioxid capacity of 12 per cent. by volume. In the later stages of this fall of

28. Aub, J. C.: Am. J. Physiol. **54**:388 (Dec.) 1920.

pressure, there might have been a lessening of the carbon dioxid content of the blood because of uniform respiration in the presence of diminished metabolism, but the drop of pressure could hardly be accounted for on the basis of hyperpnea. From all this evidence, it seems probable that the conditions Henderson established in his experiments do not account for the results observed in cases in human beings, and that the reduced alkali may be explained as a consequence of diminished volume-flow to the tissues.

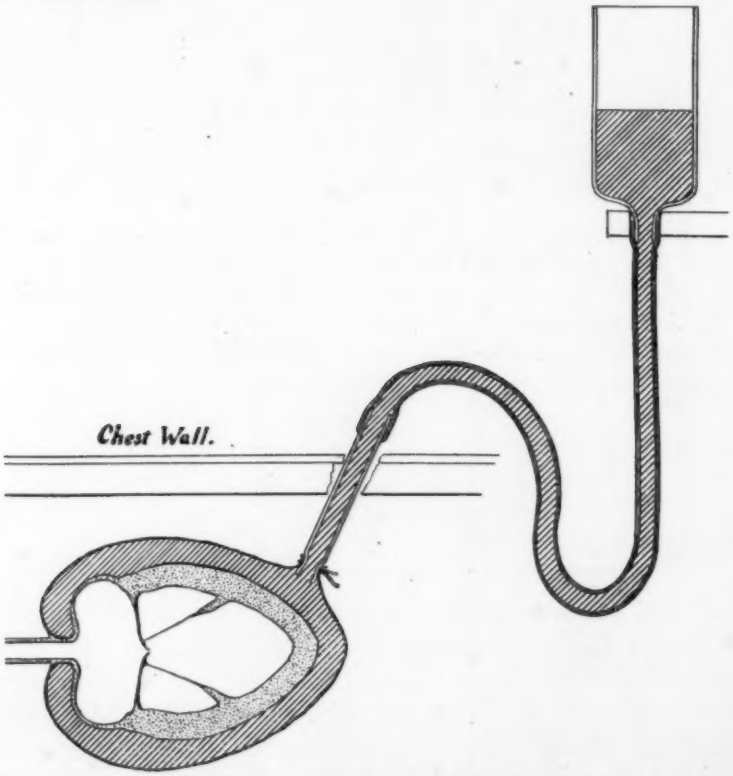

Fig. 1.—Arrangement for controlling the cardiac output and consequently the height of arterial pressure by means of increasing or decreasing intrapericardial pressure.

So far as Moore's contentions are concerned, there is no evidence that the metabolism in shock is reduced to any marked degree until there is a considerable fall of arterial pressure.[28] In other words, the low metabolism may reasonably be regarded as a consequence of the diminished oxygen supply. The reduction of the alkali reserve which has been observed to accompany a diminished oxygen supply may be satisfactorily explained, therefore, on that basis, rather than on the

28. Aub, J. C.: Am. J. Physiol. **54**:388 (Dec.) 1920.

assumption that with continued normal respiration and a diminished carbon dioxid production a primary alkalosis results, followed by escape of the excess alkali.

SIGNIFICANCE OF REDUCTION OF THE ALKALI RESERVE IN SHOCK

Experiments by Dale and Richards [29] and also by Gesell [30] have shown that a large amount of acid may be injected into the blood stream, and the alkali reserve thereby reduced to a low degree without any fall of blood pressure to a shock level. The concomitant fall of blood pressure and reserve alkali in shock, therefore, should not be regarded as indicating that a cause of shock is to be found in the lessened alkali content of the blood. Perhaps when this process reaches an extreme degree, there may be an increase of the H-ion concentration and a consequent damage to the tissues from the altered state of the blood; but in any moderate alteration of the blood, such as occurs in most cases of shock, it is probable that the diminished alkaline content in itself has no harmful influence.

On the other hand, no matter how the reduction of the alkali reserve is accounted for—either as a consequence of excessive production of acid or as a consequence of overbreathing, due to oxygen want—it is an indication of a fundamental difficulty occurring in the body, namely, an insufficient oxygen supply. We have already pointed out the need of continuous delivery of oxygen to the tissues. The failure of delivery of sufficient oxygen to the brain is likely to affect profoundly the normal metabolism of nerve cells in particular, and to lead to a disturbance of their functions. It becomes a matter of importance, therefore, to know at what point in an impaired circulation the oxygen delivery to organs becomes inadequate.

Although a reduction of blood volume affects to a great degree the volume-flow of blood to peripheral organs, as Gesell has proved, it is interesting to note that in several of the experiments which he reports [30] (Figs. 3 and 4), there is no marked reduction of the carbon dioxid content of arterial blood in a series of determinations, until the blood pressure falls to the neighborhood of 80 or 90 millimeters of mercury. Raymund [31] likewise has reported cases of experimental shock in which, after the initial reduction of the blood alkali attributable to etherization, a further reduction does not take place until the blood pressure falls below approximately 80 or 90 mm. of mercury. A similar relation is seen in several experiments performed by Henderson and Hag-

29. Dale and Richards: Report of the Shock Committee, English Medical Research Committee, October, 1918, Series No. 25, p. 250.

30. Gesell, R.: Am. J. Physiol. **47**:481 (Jan.) 1919.

31. Raymund, B.: Am. J. Physiol. **53**:127, 130 (Aug.) 1920; Figures 2, 3 and 5*b*.

gard.[32] These results are in interesting agreement with both experimental and clinical studies which were carried on in France. This concordant testimony has practical importance. In the first place, it signifies that, though the reduced volume-flow is a highly disturbing condition, the final touch in rendering the circulation inefficient is ascribable to a slowing of the blood flow as the arterial head of pressure falls. In the second place, the observation has significance because of the ease of determining the head of arterial pressure by clinical

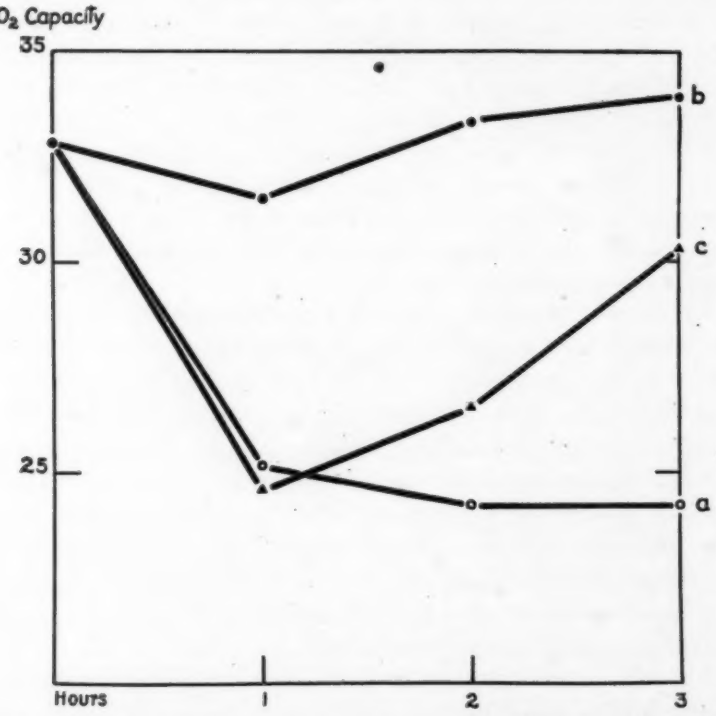

Fig. 2.—Changes in percentage by volume of carbon dioxid (the alkali reserve) of the blood plasma in cases in which the blood pressure was lowered to 60 millimeters of mercury for three hours; in *a* without other action, in *b* with previous injection of morphin, and in *c* with morphin injected after one hour of low pressure.

means and thus having a basis for a judgment as to whether the impairment of the circulation has reached a dangerous degree.

EXPERIMENTAL DETERMINATION OF THE CRITICAL LEVEL

In order to produce experimental conditions which would be as closely as possible analogous to those which analysis has shown to be

32. Henderson, Yandell, and Haggard, H. W.: J. Biol. Chem. **33**:365 (Feb.) 1918.

true for shock, and yet preserve the possibility of controlling accurately these conditions, we have made use of the arrangement illustrated in Figure 1, a modification of the method employed by Johansson and Tigerstedt [33] for recording the volume changes of the heart. Under artificial respiration, the thorax was opened between the ribs on one side at the level of the lower end of the sternum. A small slit was cut in the pericardium and a glass cannula tied in place. The thorax was then tightly closed and the animal allowed to breathe naturally. A small funnel was connected with the cannula by means of rubber tubing and filled with physiologic sodium chlorid solution or with 6 per cent. acacia in physiologic sodium chlorid solution. The pressure of the column of fluid was transmitted to the outside of the heart in the pericardial sac, and thus affected directly the filling of the organ and conse-

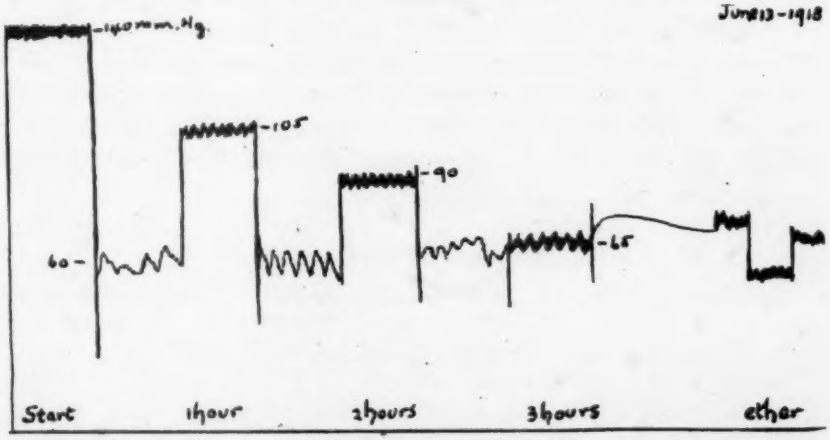

Fig. 3.—Gradual failure of the blood pressure to rise as the pressure is held at 60 millimeters of mercury for successive periods of one hour and then released for five-minute intervals.

quently its output. By raising or lowering the funnel, any desired arterial pressure could be produced and maintained. In a few experiments, the arterial pressure was regulated by compression of the heart by means of a clamp applied to the chest. This method gave similar results, but was inferior in that it interfered with the respiratory movements.

Most of the experiments were performed on cats; but in a few cases, rabbits or dogs were used. Ether was found to be a satisfactory anesthetic, for preliminary observations showed that under the conditions of our experiments it produced no effect on the alkali reserve. A cannula was placed in the pericardium to control the arterial pressure,

33. Johansson and Tigerstedt: Skandin. Arch. f. Physiol. **1**:344, 1889.

as described above. The blood pressure was recorded by a mercury manometer connected with one carotid; a second cannula was placed in the other carotid or in the femoral artery to obtain samples for the bicarbonate determinations. For each determination, about 3 c.c. of blood was taken in a graduated tube, centrifuged, and the alkali reserve of the plasma determined by the Van Slyke [7] method. A sample of blood was usually taken immediately before reducing the blood pressure and at intervals of an hour throughout the course of the experiment. As a rule, no difficulty was experienced in keeping a constant arterial pressure at any desired level. Sometimes, just after reducing the pressure, it was necessary to adjust the funnel repeatedly in order to hold the arterial pressure constant, but usually an equilibrium was reached in a short time. A few experiments had to be discarded on account of irregularities in pressure.

Throughout the whole series of observations, a satisfactorily constant relation was found between the degree of reduction of the alkali reserve and the lowering of blood pressure. The most marked reduction was found at low pressures, whereas above 80 millimeters of mercury the state of the blood remained unchanged. These differences can be shown by a few illustrative protocols.

PROTOCOLS OF EXPERIMENTS

EXPERIMENT 2.—May 10, 1918, cat, 3.6 kilograms. Ether; cannula in both carotids.

10:08: Blood pressure 178 mm.; temperature 36 C.
10:22: Blood pressure 160 mm.
10:23: Sample A, 3 c.c. blood; carbon dioxid reading 39 per cent. by volume.
10:24: Blood pressure 160 mm.
10:26: Arterial pressure reduced to 80 mm. by external pressure on chest.
11:27: Sample B, 3.2 c.c. blood; carbon dioxid reading 37.
12:24: Sample C, 3.0 c.c. blood; carbon dioxid reading ?; sample lost.
12:57: Sample D, 3.5 c.c. blood; carbon dioxid reading 38.
1:29: Pressure reduced to 60 mm.
2:28: Sample E, 2.7 c.c. blood; carbon dioxid reading 35.
3:01: Pressure removed from thorax; blood pressure gradually rose until 4:00 when it reached 112 millimeters of mercury.
4:01: Sample F, 4.5 c.c. blood; carbon dioxid reading 40.

EXPERIMENT 3.—May 11, 1918, cat, 2.9 kilograms. Ether; cannulas in both carotids; cannula in pericardium.

9:51: Blood pressure 124 mm.
9:53: Sample A, 5.0 c.c.; carbon dioxid reading 30.
10:00: Blood pressure fell to 80 mm.; kept at the level by intrapericardial pressure.
11:02: Sample B, 4.5 c.c.; carbon dioxid reading 31.
11:04: Pressure reduced to 60 mm.
12:03: Sample C, 4.0 c.c.; carbon dioxid reading 20.

12:08: Intrapericardial pressure removed; blood pressure rose to 116 millimeters of mercury.

12:31: Sample D, 4.0 c.c.; carbon dioxid reading 25.

12:32: Pressure reduced to 70 mm.

1:31: Sample E, 4.5 c.c.; carbon dioxid reading 23.

EXPERIMENT 16.—May 25, 1918; dog, 6.73 kilograms.

7:35: Morphin 0.056 gm.

8:45: Operation started; cannula in pericardium; carotid cannulas.

9:50: Sample A, 3.0 c.c.; carbon dioxid reading 33.

9:52: Blood pressure 120 mm.

10:12: Blood pressure 116 mm.

10:17: Blood pressure reduced to 60 mm. by intrapericardial pressure (gum-salt).

11:17: Sample B, 4.5 c.c.; carbon dioxid reading 22.

12:22: Sample C, 6.0 c.c.; carbon dioxid reading 20.

1:22: Sample D, 6.2 c.c.; carbon dioxid reading 19.

2:31: Sample E, carbon dioxid reading 20.

TABLE 4.—BLOOD PRESSURE REDUCED TO 80 MM.

Exp.	Animal	Orig. Blood Pressure	Carbon Dioxid Reading			
			Start	1 Hour	2 Hours	3 Hours
5/10	Cat	178	39	37	..	38
5/11	Cat	124	30	31	..	..
5/15	Dog	80	35	35	..	..
5/16	Dog	160	20	20	17	..
			Av. 31.0	30.8		

TABLE 5.—BLOOD PRESSURE REDUCED TO 70 MM.

Exp.	Animal	Orig. Blood Pressure	Alkaline Reserve				
			Start	1 Hour	2 Hours	3 Hours	4 Hours
5/11	Cat	116	25	23	..	..	..
5/13	Cat	170	33	31	25	..	..
5/27	Cat	142	30	27	32	34	35
6/14	Cat	168	34	29	29	32	33
			Av. 30.5	27.5			

The results for the series of experiments are summarized in Tables 4, 5, 6, 7 and 8. Cases in which the blood pressure was reduced to 80 millimeters of mercury are given in Table 4. In every case, the alkali reserve was unaffected by pressure at this level for an hour. Table 5 shows the effects at 70 mm. pressure. Here there is a slight reduction in the alkali reserve—an average fall of 3 per cent. by volume of carbon dioxid. In the two cases in which observations were continued for four hours, a recovery took place. This occurred in a certain number of cases, even at lower blood pressures. The phenomenon will be referred to again. The next two tables present the results for an arterial pressure reduced to 60 millimeters of mercury, Table 6 giving

figures for cases in which the low pressure was continued for only one hour, and Table 7 for cases of low pressure for three hours. With this pressure, it will be noted that there was a marked fall in the alkali reserve during the first hour, indicating that the circulation was no longer adequate to maintain normal oxidation in the body. During the second hour, the average of the results shows a slight further fall; but during the third hour, there is no further change. Table 8, giving

TABLE 6.—Blood Pressure Reduced to 60 Mm. for One Hour

Exp.	Animal	Orig. Blood Pressure	Alkaline Reserve		
			Start	1 Hour	2 Hours
5/10	Cat	178	38	35	..
5/11	Cat	124	31	20	..
5/24	Rabbit	...	27	18	..
6/ 5	Cat	...	37	20	..
7/15	Cat	136	30	19	18
7/16	Cat	114	26	19	..
			31.5	21.8	

TABLE 7.—Blood Pressure Reduced to 60 Mm. for Three Hours

Exp.	Animal	Orig. Blood Pressure	Alkaline Reserve				
			Start	1 Hour	2 Hours	3 Hours	4 Hours
5/ 9	Cat	130	39	36	32	32	..
5/25	Dog	120	33	22	20	19	20
5/29	Cat	128	35	32	33	33	..
6/13	Cat	140	31	14	18	19	..
7/13	Cat	118	37	29	29	27	29
7/20	Cat	109	33	30	25	27	..
			34.7	27.1	26.1	26.1	

TABLE 8.—Blood Pressure Reduced to 50 Mm.

Exp.	Animal	Orig. Blood Pressure	Alkaline Reserve			
			Start	1 Hour	2 Hours	3 Hours
5/28	Cat	174	27	14	11	..
6/ 5	Cat	...	37	19	..	..
7/18	Cat	86	28	20	23	21
7/23	Cat	96	41	29	..	17
			Av. 33.2	20.5		

effects of the reduction of the blood pressure to 50 millimeters of mercury, reveals a still greater fall in the alkali reserve; at the end of one hour, the percentage by volume of carbon dioxid reached the low figure of 20.5.

An examination of the data presented in the accompanying tables shows a normal bicarbonate reserve in the cat of from 39 to 25, the average being about 32. This is a much lower figure than that found in normal human plasma, where a reading below 50 is generally considered to be pathologic. The most rapid fall in the alkali reserve occurs

during the first hour of reduced pressure, after which it soon reaches a stationary low level. In a few cases, there is an actual recovery after several hours. It may be that by lessened cellular activity the organism adapts itself to the condition of low pressure; and then, because the oxygen requirement becomes less, the acids may be reduced by oxidation. There is another possibility which might be considered. Clearly, if the pressure is artificially kept constant throughout an experiment, it is possible that after several hours a peripheral dilatation takes place, due to lessened vasomotor tone or to direct effect of metabolites, and thus with a constant pressure the blood flow would be increased.

The alkali reduction produced by an inadequate circulation is not permanent, but rapidly disappears when the blood pressure is allowed to return to normal, as is shown above in the first two protocols. In a number of other instances, the blood pressure was raised by injection of gum-salt solution, and the alkali reserve was restored.

TABLE 9.—Results Obtained in Four Animals in Which Pressure was Reduced to 80 or 90 Mm. After Removing 20 Per Cent. of Blood

	Blood Pressure		Alkali Reserve		
Exp.	Orig.	Final	Start	1 Hour	2 Hours
5/14	175	80	31	26	23
5/21	150	80	20	16	..
5/23	100	90	37	35	35
6/16	150	90	33	33	..

Many cases of low blood pressure in wounded men were complicated by hemorrhage. The question arose as to whether loss of blood modified the critical level of the blood pressure. This was somewhat difficult to determine experimentally because in many animals the combination of an operation and the loss of blood reduces the blood pressure below the desired level. Satisfactory results were obtained in four animals (Table 9). In each case, they were bled 20 per cent. of their calculated blood volume before reducing the pressure. The two cases with arterial pressure reduced to 80 millimeters of mercury showed marked indications of an inadequate circulation, while those with a reduction to only 90 mm. showed less effect. It seems probable, therefore, that when hemorrhage complicates a low blood pressure the critical level is higher than when no loss of blood has occurred.

From these experimental results we conclude that the *critical level*, that is, the level at which the blood pressure is no longer capable of maintaining an adequate volume-flow to the tissues, and thus serving the normal oxidations of the body, is *approximately* 80 millimeters of mercury. Above 80 mm. reduction of the alkali reserve is not likely to appear; but as the pressure falls below this, a reduction will probably occur, which is more marked and develops the more rapidly the lower

the pressure. If there has been a loss of blood, the circulation becomes inadequate before the pressure falls to 80 millimeters of mercury, i.e., the critical level is raised. In this connection, the observations of Markwalder and Starling[34] are of interest. They found experimentally that cardiac contraction begins to weaken when the arterial pressure falls below 90 millimeters of mercury. Gruber[35] noted a marked decrease in the height of contraction of muscle which was being uniformly stimulated when he reduced the blood pressure to 90 millimeters of mercury. Above this level, however, changes in pressure produced practically no effect on muscular contraction. The results reported by Gesell, by Raymund and by Henderson and Haggard, mentioned above, likewise point to a pressure of 80 or 90 millimeters of mercury as being necessary for a sufficient blood flow.

Aub has studied the decrease of the metabolic rate in shock. In eight cases of severe shock, the average decrease was 33 per cent.[28] It was a matter of interest to learn whether the fall of metabolism was related in any way to the critical level of arterial blood pressure, as indicated by the appearance of acidosis. Aub found, indeed, that as a rule the critical level for metabolism was associated with a blood pressure in the neighborhood of 75 or 80 millimeters of mercury. At that level, the metabolism might be within the normal rate of variation; but usually when this was the case, the blood pressure had been remaining stationary or was rising. In other instances, he noted that when the blood pressure was at this level, or occasionally higher, the metabolism might be considerably reduced; but when this was the case, the blood pressure was in the process of falling. With a blood pressure below 75 millimeters of mercury the metabolism was invariably reduced beyond the common normal variations. These observations are confirmatory of the evidence already adduced in placing the threshold of adequacy of arterial pressure at approximately 75 or 80 millimeters of mercury.

THE EFFECT OF MORPHIN

As shown in Table 7, reduction of the blood pressure to 60 millimeters of mercury for three hours causes a marked and lasting reduction of the alkali of the blood plasma. Experiments performed by one of us (M.C.) at Dijon proved that morphin can modify this effect in a striking manner. A comparison of the average figures in Tables 10 and 11 with those in Table 7 is given graphically in Figure 2. The curves of each condition have been shifted so that they have a common initial point at the average of the first readings (32.8). Figure 2 *a* represents the results detailed in Table 7—a fall and continued low level of the

34. Markwalder and Starling: J. Physiol. **47**:279, 1913.
35. Gruber: Am. J. Physiol. **32**:227, 1913.

blood alkali when the blood pressure is held down to 60 millimeters of mercury. Figure 2 *b* represents Table 11, and Figure 2 *c* Table 10. In the former case, morphin sulphate (20 mg. per kilogram) was given subcutaneously just before the pressure was lowered; the alkali reserve was not reduced. In the latter case, it was given after the pressure had been kept at 60 mm. for one hour; the alkali reserve, which had fallen as in *a*, began to rise, and after two hours was largely restored.

TABLE 10.—Effects of Morphin Given One Hour After Reduction of Blood Pressure to 60 Millimeters of Mercury

Exp.	Animal	Orig. Blood Pressure	Alkaline Reserve				
			Start	1 Hour	2 Hours	3 Hours	4 Hours
6/ 7	Dog	138	24	15	11	12	18
6/ 8	Dog	128	23	16	20	22	23
6/10	Cat	150	35	21	27	29	34
6/17	Cat	120	35	35	37	42	..
6/18*	Cat	118	30	20	21	31	..
6/19*	Cat	150	32	23	23	28	..
6/20	Cat	156	36	21	23	22	22
6/24	Cat	120	26	24	29	35	36
		Av.	30.1	21.9	23.9	27.6	

TABLE 11.—Effects of Morphin Given Just Before Reducing Blood Pressure to 60 Millimeters of Mercury

Exp.	Animal	Orig. Blood Pressure	Alkaline Reserve				
			Start	1 Hour	2 Hours	3 Hours	4 Hours
6/26	Cat	100	32	34	39	37	35
6/27	Cat	134	35	32	36	37	39
6/29	Cat	142	29	27	27	31	33
7/ 8	Cat	114	41	33	35	34	..
10/27*	Cat	128	30	34	33	32	..
10/29*	Cat	120	34	33	34	37	35
		Av.	33.5	32.2	34.0	34.7	

The explanation of this conserving influence of morphin is still obscure. Henderson and Haggard [27] have reported that when, by means of morphin, respiration is depressed and the alveolar carbon dioxid is raised, the alkali reserve of the blood also rises; and they suggest that this rise is due to a passage of alkali from the tissues into the blood to compensate for the increase in carbonic acid. The reactions represented in Figure 2 *b* and *c*, however, occur in animals in which the breathing is kept mechanically regular by artificial respiration. In Table 10, the experiments of June 18 and 19, and in Table 11, the experiments of October 27 and 29 (marked by asterisks) were of this character. They do not differ in nature from the other experiments in the series in which the respiratory mechanism of the animal was allowed to function. It seems, therefore, that slowing of the respiration is not solely responsible for the preservation of the normal alkali reserve.

Possibly morphin, by reducing the activity of tissues, lessens their demand for oxygen and thus compensates for the smaller supply of oxygen in the sluggish blood flow. Further experiments are needed, however, before this suggestion should be accepted.

CLINICAL EVIDENCE FOR A CRITICAL LEVEL

After obtaining the foregoing experimental indications of a critical level, we went over the Béthune records of low blood pressure in cases of shock and hemorrhage in which determinations of the alkali reserve had been made simultaneously. These records were then tabulated on the basis of systolic blood pressure. The figures are given in Table 12. As the table shows, the alkali reserve rarely falls below

TABLE 12.—CRITICAL LEVEL OF BLOOD PRESSURE IN HUMAN CASES AS SHOWN BY THE ALKALI RESERVE (CARBON DIOXID CAPACITY)

Systolic Blood Pressure	Average Carbon Dioxid Capacity Percentage by Volume	Variation	No. of Cases
96–102	48	40–56	5
90– 92	49	41–58	7
82– 86	49	43–52	5
72– 78	43	30–49	10
62– 68	36	21–42	11
52– 59	24	20–27	5

the normal (approximately 50 per cent. by volume) until the systolic pressure lies below 80 millimeters of mercury. Furthermore, the greater the reduction of blood pressure below this critical level, the greater is the reduction of the carbon dioxid capacity or the alkali reserve. The significance of these observations will become more manifest as we consider how the reduced pressure is related to the damage suffered by sensitive structures when insufficiently supplied with oxygen.

VARYING SENSITIVENESS OF TISSUES TO WANT OF OXYGEN

In an extensive series of studies, Pike, Guthrie, and Stewart have examined the capacity of different tissues of the body to function after having been totally deprived of their blood supply for varying periods. In general, it may be stated that muscles and glands reveal a remarkable endurance of anemia.[36] The muscles will withstand this injurious condition much longer than the nervous system, for example. The same may be said of glandular structures.

The most sensitive cells in the body are found in the brain; but a remarkable gradation of resistance to anemia is found in different neurons. Most sensitive of all are cells of the cerebellum and cerebrum.

36. Pike, Guthrie and Stewart: Am. J. Physiol. **22**:51, 1908.

Mayer,[37] Batelli,[38] and also Stewart, Guthrie, Burns and Pike[39] have offered concordant evidence that after fifteen minutes of anemia, restoration of cerebral function is no longer constant. Gomez and Pike,[40] on examining the effects in detail, observed that the small pyramidal cells of the cortex are especially sensitive—eight minutes of anemia killed many of them—and that the Purkinje cells were next in order—thirteen minutes producing chromatolysis in them.

The cells of the medulla are more resistant. Gomez and Pike found that anemia for from eight to thirteen minutes produces in them only slight lesions or no changes at all, and that anemia should last for twenty to thirty minutes in order to produce alterations incompatible with complete recovery. The cells of the spinal cord apparently withstand a lack of blood flow for a somewhat longer period than those of the bulb; different observers have reported paralysis or recovery after shutting off the blood supply from forty-five to sixty minutes.[41] The outlying ganglions of the sympathetic chain, according to Schröder,[42] are even less delicate, for they can be completely deprived of blood supply for an hour and will then function if supplied with blood. Cannon and Burket[41] showed that the nerve cells of the myenteric plexus will endure anemia for as long as three hours without showing either loss of function, or change or disappearance of structure. From this evidence, it is clear that in the nervous system there is a hierarchy of cells with varying ability to meet the circumstances of insufficient oxygen supply.

In shock, of course, there is not a total absence of oxygen delivery to the tissues, as in the experiments reported in the foregoing paragraph. On the other hand, the indications are definite that even with the blood flowing, conduction in the nervous system may be completely checked when the oxygen supply becomes insufficient. In some experiments performed by E. L. Porter,[43] on variations in the irritability of a reflex arc under asphyxial conditions, it was discovered that when the oxygen supply is diminshed and accumulation of carbon dioxid in the blood is prevented, the reflex abruptly disappears when the oxygen content of the arterial blood is reduced on the average to 4.5 per cent. by volume. Lack of oxygen proved to be much more important than accumulation of carbon dioxid in abolishing the capacity to transmit nerve impulses.[44]

37. Mayer: Centralbl. f. d. med. Wissensch. **16**:579, 1878.
38. Batelli: J. de physiol. et de path. gén. **2**:456, 1900.
39. Stewart, Guthrie, Burns and Pike: J. Exper. M. **8**:316, 1906.
40. Gomez and Pike: J. Exper. M. **11**:262, 1909.
41. Cannon and Burket: Am. J. Physiol. **32**:348, 1913.
42. Schröder: Arch. f. d. ges. Physiol. **116**:603, 1907.
43. Porter, E. L.: Am. J. Physiol. **31**:244, 1913.
44. Porter, E. L.: Reference 43, p. 231.

EVIDENCE OF DAMAGE TO THE CENTRAL NERVOUS SYSTEM FROM LOW BLOOD PRESSURE

The testimony that insufficient blood supply injures the elements of the central nervous system is both morphologic and functional.

Morphologic changes as a consequence of diminished blood flow have been reported by Dolley,[45] who found that after repeated hemorrhage the Purkinje cells of the cerebellum underwent a sequence of alterations exactly identical with those observed in shocked animals. Mott[46] has reported studies of the cell changes in cases of shock in which some hours before death there was low blood pressure, and has found that there is general chromatolysis, a change which he attributes to the prolonged anoxemia. Besides the chromatolysis, Mott noted that many of the cells of the medulla and also some of the Purkinje cells show a tendency to profuse purple staining when a double stain, such as a basic blue and eosin dye, is used. This alteration in the staining reaction denotes a biochemical change, possibly different in character from that associated with the diffusion of the Nissl substance.

The functional evidence of injury to the nervous system from low blood pressure has come mainly from examination of disturbances in vascular reflexes during the development of shock. W. T. Porter and his collaborators proved that after a prolonged low blood pressure in shocked animals stimulation of afferent nerves could cause either a rise or fall of blood pressure.[47] They concluded, therefore, that even in extreme shock the vasomotor center is still active. It was not, however, until perfusion experiments were performed on peripheral vessels still connected with the vasomotor center that direct proof was obtained showing whether the center was overactive or underactive. Such perfusion experiments conducted by Erlanger, Gesell and Gasser,[48] and more recently by Cattell,[49] have demonstrated that although in the early stages of shock, whether due to abdominal injury or to crushing of muscle, the vasomotor tone is increased. In the later stages, there is practically invariably diminished tone and lessened peripheral resistance. The tendency of the vasomotor center, when the blood pressure becomes low, is to compensate by increased activity. The failure of the center to respond thus to the stimulus of a low pressure in the late stages of shock must be regarded, therefore, as signifying that the center has become injured to such a degree that it is incapable of responding.

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45. Dolley: J. M. Research, **16**:96, 1909.

46. Mott: Report of the Shock Committee, English Medical Research Committee, March, 1919, Series No. 26, p. 46.

47. Porter, W. T.: Am. J. Physiol. **20**:399, 1907; ibid. **20**:500, 1908.

48. Erlanger, J.; Gesell, R., and Gasser, H. S.: Am. J. Physiol. **49**:151 (July) 1919.

49. Cattell, McKeen, quoted by Cannon, W. B.: Arch. Surg. **4**:1 (Jan.) 1922.

Bayliss [50] has pointed out that the vasomotor center is not the only bulbar center that suffers from low blood pressure and the consequent sluggish blood flow. He noted that when the average blood pressure remained below 58 millimeters of mercury in cats, not only were vasomotor reflexes abolished but the rate of respiration fell to 6 or less per minute. Various other experiments showed that when the blood pressure was less than 70 millimeters of mercury from one and a half to two hours, more or less, a paralysis of the bulbar centers would occur. The respiratory center in the cat appears to suffer before the vasomotor center, though it may continue to discharge at the slow and ineffective rate of 3 or 4 per minute when the vasomotor center has lost its excitability. Bayliss suggests that different animals probably behave differently as regards the order in which their vital centers fail and that in man the vasomotor center may begin to lose its functional stability before the respiratory center.

In order to secure evidence as to the progressive nature of the damage done to the nervous control of the circulation in consequence of an insufficient blood flow, we have made observations on the effects of reducing the blood pressure to 60 millimeters of mercury for varying times by the method of intrapericardial compression of the heart (see p. 314). When the pressure had been thus reduced to that level it was held there for an hour. The compression of the heart was then released by lowering the fluid column. Usually, when this is done, the blood pressure will be restored completely or nearly completely to its normal level (Fig. 3). If then the pressure is again lowered to 60 mm. and held there for an hour, it does not rise so high; and when held to this low level for another hour, it may not rise at all.

It might be supposed that the failure of the pressure to rise after being held persistently low for three hours would be due to a loss of blood volume by escape of plasma into the tissues through more permeable capillary walls. Observations with the hematocrit in these cases, however, suggest that this was not an important factor. In Table 13 are the average hematocrit readings when the pressure was reduced to different levels and held there for periods of one, two and three hours. As the figures clearly show, the percentage of corpuscles gradually fell, indicating that there was a dilution, rather than a concentration, of the arterial blood.

The explanation which appears most reasonable to account for the failure of the pressure to rise after persistence at the low level is that the nervous agencies which control the circulation have suffered damage —a damage due to inadequacy of the circulation itself. The reason-

50. Bayliss, W. M.: Intravenous Injections in Wound Shock, London, New York, Longmans, Green & Co., 1918, p. 11.

ableness of the conclusion is supported by observations on relaxation of vascular tone in late shock,[49] and by tests of the responsiveness of the vasomotor center to stimulation by asphyxia. At an early stage in shock, there may be an asphyxial rise of pressure, and later, though the heart still beats and respiration is still active, the asphyxial rise does not occur, i. e., the vasomotor cells are no longer excited by the blood

TABLE 13.—HEMATOCRIT READINGS AFTER REDUCTION OF THE BLOOD PRESSURE BY INTRAPERICARDIAL COMPRESSION

No. of Cases	Pressure Reduced to Mm. Hg	Average Hematocrit Readings (Percentage of Corpuscles)			
		Start	1 Hour	2 Hours	3 Hours
4	70	47	46	46	47
12	60	40	37	31	27
4	50	38.5	34.5	26	26

changes. LaCroix[51] has noted that in cases of shock after severe wounds there may be total immobility of the pupil, no matter how intense the light. This failure of the pupillary reaction points to a block of the nerve impulses along the reflex path involved in the reaction and is further indication of injury to the nervous elements.

IMPORTANCE OF THE TIME FACTOR IN THE DEVELOPMENT OF SHOCK

Experiments cited above have definitely proved that with an acute lack of oxygen nerve cells abruptly cease to function. The loss of consciousness when one faints is a common example of the close dependence of nervous elements on continuous oxygen supply. The experimental and clinical observations on the effects of prolonged low pressure point to the fact that these sensitive cells may be gradually harmed, if, instead of acute anemia, there is prolonged partial anemia.

The gradually damaging effect of persistent low blood pressure is of the utmost importance both in understanding and in treating shock. When the vasomotor center has lost its capacity to maintain vascular tone, there is no sort of remedial agent which can be applied to bring the blood flow back to its normal condition. If, in an animal, the medulla is destroyed, the blood pressure falls to approximately 40 millimeters of mercury and there remains. Intravenous injections of blood or other fluid will raise the pressure for only a few moments. An incredible amount of fluid may thus be introduced into the vessels without any lasting rise of pressure. When a man has been in a state of shock for a long time, so that the vasomotor center fails to hold the blood vessels in a state of moderate contraction, he reacts much as the experimental animal does when the bulbar centers are destroyed.

51. La Croix: Bull. et mém. Soc. de Chir. de Paris, **44**:906, 1918.

Transfusion leads to no permanent gain—the beneficial effect is fleeting. When that stage has been reached, the secondary harm from insufficient oxygen has been too great to permit resuscitation.

The foregoing considerations emphasize the prime importance of early treatment of the low blood pressure of shock. As Pike and Coombs [52] have stated, injured nerve cells require a better blood supply for their restoration than uninjured nerve cells do for their maintenance. Thus, though the tissues may not suffer until blood pressure has fallen below a critical level of approximately 80 millimeters of mercury, it is desirable, when the pressure has fallen below this level and has shown no evidence of rising, that it be raised to the normal level of 120 millimeters of mercury, if possible, in order to provide the most favorable conditions for repair of the damage which has been done.

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52. Pike, F. H., and Coombs, H. C.: Relation of Low Blood Pressure to a Fatal Termination in Traumatic Shock, J. A. M. A. **68**:1892 (June 23) 1917.

POSTOPERATIVE INTRA-ABDOMINAL HERNIA

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Moynihan,[1] in his monograph on retroperitoneal hernia, directs attention to the possibility of herniation of the small intestine into the lesser peritoneal cavity through an abnormal aperture in the transverse mesocolon. Four such hernias have been reported, one by Boettcher[2] in 1878. In 1885, von Hacker[3] suggested the advisability of performing a gastrojejunostomy by the posterior route, making the anastomosis in the posterior wall of the stomach through an opening in the transverse mesocolon. Thus, seven years before the retrocolic method of gastrojejunostomy was advocated, attention had been directed to the possibility of the small bowel herniating through an opening in the transverse mesocolon. This fact, evidently, was lost sight of, because it was only after fatalities from such hernias that surgeons began to suture the stomach or jejunum to the transverse mesocolon. Mayo-Robson,[4] Moynihan,[1] Mikulicz,[5] and others have reported cases of this type. In the older textbooks,[6] suturing the opening in the transverse mesocolon to the stomach or jejunum before making the anastomosis (between the stomach and the jejunum) was advised. Of late years, this procedure has been reversed: the anastomosis is made first, and the sutures are placed afterward. MacArthur,[7] however, for some time has reverted to the older method, considering it more advantageous to close the opening before performing the anas-

1. Moynihan, B. G. A.: Retroperitoneal Hernia, Ed. 2, London, Bailliere, Tindall and Cox, 1906, pp. 162-163.

2. Boettcher, A.: Hernia bursae omentalis mit im Mesocolon Transversum befindlicher Bruchpforte, Arch. f. path. Anat. u. Physiol. u. f. klin. Med. **72**:642-644, 1878.

3. Von Hacker: Zur Casuistik und Statistik der Magenresectionen und Gastro-enterostomieen, Arch. f. klin. Chir. **32**:616-625, 1885.

4. Mayo-Robson, A. W., and Moynihan, B. G. A.: Diseases of the Stomach, London, Bailliere, Tindall and Cox, 1904, pp. 257-258.

5. Von Bergmann, E.: von Bruns, P., and von Mikulicz, J.: System of Practical Surgery, Philadelphia, Lea & Febiger **5**:439, 440, 444, 1904.

6. Von Bergmann, E.; von Bruns, P., and von Mikulicz, J.: Footnote 5. Kocher, T.: Operative Surgery, London, Adam and Charles Black, 1911, p. 571. Bryant, J. D.: Operative Surgery, New York, D. Appleton & Co. **2**:913, 1905.

7. MacArthur: Personal communication.

tomosis, for in this manner the posterior portion of the aperture may be securely closed.

As the number of gastrojejunostomies increased, another form of internal hernia was observed. The small intestine slipped behind the loop of jejunum which is formed by every anastomosis, whether it is antecolic or retrocolic. Mikulicz [5] recognized this and stated that the symptoms produced were due to compression of the root of the mesentery rather than to incarceration of the intestine. Mayo-Robson and Moynihan,[4] in speaking of a case occurring after anterior gastrojejunostomy, reported by W. J. Mayo,[8] say, "The passage of the small intestine through the loop formed by the juncture of the jejunum and stomach is probably only possible, certainly only probable, after the anterior operation."

Moschcowitz and Wilensky,[9] in 1915, collected seven cases from the literature reported by Steudel,[10] Petersen,[11] W. J. Mayo,[8] Gray,[12] Gordon,[13] and Barker,[14] and one of their own. Bryan,[15] in 1920, reported a similar case occurring twelve days after posterior gastrojejunostomy, in which the small intestine had passed from right to left, behind the anastomosis. The hernia was reduced by operation. Four days later, a similar herniation occurred and a third operation was necessary. The patient recovered. Deaver and Ashhurst [16] reported a case, without details. They consider that the complication is more likely to occur after a long loop posterior gastrojejunostomy than after a short loop.

A summary of the ten cases reported from the literature shows that the hernia occurred in six cases following the posterior type of gastrojejunostomy (four with short loops and two with long loops); in two cases following the anterior type, and in two the type was not given.

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8. Mayo, W. J.: Complications Following Gastro-Enterostomy, Ann. Surg. **36**:231-244, 1902.

9. Moschcowitz, A. V., and Wilensky, A. O.: Intestinal Obstruction Consecutive upon Posterior Retrocolic Gastro-Enterostomy, with Description of a Method to Avoid Similar Complications, Surg., Gynec. & Obst. **21**:390-393, 1915.

10. Steudel: Die in den letzten Jahren an der Czernyschen Klinik ausgeführten Magenoperationen und die Endresultate der früheren Operationen, Beitr. z. klin. Chir. **23**:1-88, 1899.

11. Petersen, W.: Ueber Darmverschlingung nach der Gastro-Enterostomie, Arch. f. klin. Chir. **12**:94-114, 1900.

12. Gray, H. M. W.: A Cause of Intestinal Obstruction After Gastro-Enterostomy, Lancet **2**:526, 1904.

13. Gordon: Lancet **2**:1477, 1905.

14. Barker, A. E.: A Remarkable Sequel to a Case of Gastro-Enterostomy, Lancet **2**:1277-1278, 1904.

15. Bryan, R. C.: Recurrent Internal Hernia Following Gastro-Enterostomy, Surg., Gynec. & Obst. **30**:82-85 (Jan.) 1920.

16. Deaver, J. B., and Ashhurst, A. P. C.: Surgery of the Upper Abdomen, Philadelphia, P. Blackiston's Son & Co. **1**:435, 1909.

The more frequent occurrence of the hernia following the posterior operation might seem ambiguous were it not explained by the fact that a far greater number of posterior gastrojejunostomies are performed than anterior.

In seven cases, the hernia started on the right side and traveled toward the left. In one case it started on the left side and traveled toward the right. The time elapsing between the gastro-enterostomy and the second operation was six days in four cases; eight days in one; twelve days in two; fourteen days in one; one year in one, and two years in one. Four patients died, and four recovered; the final results were not stated with regard to two. We have not found, in the literature, mention of this form of internal hernia following colostomy. The possibility that this catastrophe may follow the Polya operation, anterior or posterior, should, however, be considered. Two cases of internal hernia following gastrojejunostomy, and one following colostomy are reported herewith.

REPORT OF CASES

CASE 1 (A 357800). — *History.* — Mr. R. D., aged 35, came to the clinic, May 11, 1921, complaining of having had a dull, heavy feeling in the epigastrium for ten years. The pain occurred from three to four hours after meals, and was relieved by food and soda. The patient was nauseated but did not vomit. The attacks lasted for about one month; he was then perfectly well for about six months. The bowels had been constipated for ten years.

Examination.—The patient had lost 11 pounds (5 kg.) in six months. The systolic blood pressure was 124 and diastolic 76. The urine contained an occasional red blood cell. Blood examination revealed: hemoglobin 77 per cent.; erythrocytes, 4,690,000, and leukocytes, 9,300. The Wassermann reaction was negative. Examination of the gastric contents revealed: total acids, 42, and free hydrochloric acid, 40. Duodenal ulcer was revealed by the roentgen ray.

Operation.—May 18, 1921, an ulcer was found on the anterior wall of the duodenum just below the pylorus. It was impossible to perform a posterior gastro-enterostomy on account of the short mesentery of the transverse colon. The jejunum was brought up over the colon (12-inch [30.5 cm.] loop), and attached to the stomach, making an anterior gastro-enterostomy. The stomach and gallbladder appeared to be normal. The appendix, which was chronically inflamed, was removed.

Course.—The first three days of convalescence were uneventful. On the evening of the third day, however, the patient felt nauseated. The stomach tube was passed and 15 ounces (444 c.c.) of bile-stained fluid was recovered. During the night, he hiccuped and frequently vomited small amounts of bile-stained fluid. The stomach tube was passed in the morning, and 24 ounces (710 c.c.) of the same kind of material was obtained. The evening of the fourth day, only one-half ounce (15 c.c.) of greenish material was recovered and the patient appeared to be better. On the following day, he was able to take ginger ale without nausea or vomiting. His condition remained about the same until the morning of the eighth day when 12 ounces (355 c.c.) of

greenish fluid was recovered by the stomach tube. One ounce of castor oil was given, which was promptly vomited. The morning of the ninth day, the patient vomited 2 ounces (59 c.c.) of dark green fluid; and a few hours later 24 ounces (710 c.c.) was recovered by the stomach tube. The patient continued to be nauseated, and his general appearance indicated mechanical obstruction. The abdomen was opened and the condition described below was found.

The upper jejunum at a point distal to the gastro-enterostomy had slipped from right to left through the opening between the mesentery of the jejunum at the point where the gastro-enterostomy had been made and the transverse mesocolon. The entire small intestine from this point down to within a few inches of the ileocecal valve had followed the jejunum through the opening and was lying on the left side. This had produced torsion on the mesentery; and the jejunum for a distance of 1½ feet (46 cm.) distal to the gastro-enterostomy was quite dark and distended. The intestine was pulled back through the opening and the obstructed bowel immediately regained its normal color. The opening through which the bowel had slipped was closed with interrupted catgut sutures. The gastro-enterostomy was adherent to the anterior abdominal wall and to the tissues surrounding it; and in elevating the stomach, the jejunum was separated from the stomach along the suture line of the gastro-enterostomy. This opening, which was about 2 cm. long, was closed with two rows of chromic catgut. The loop of jejunum lying proximal to the gastro-enterostomy was not involved in the obstruction. When the wound was opened, seropurulent material appeared in the subcutaneous and deep tissues. The opening, which was made through the former incision, was closed with difficulty. The patient did not recover (Fig. 1).

Case 2 (A 111382).—*History.*—Mr. J. C., aged 54, came to the clinic, July 25, 1914. He had complained of a dull aching pain in the epigastrium for two months. He had belched gas freely and his bowels had been constipated. The night before examination, he had taken a saline laxative. At 4 o'clock the following morning he was awakened with a very severe knifelike pain in the middle of the epigastrium, accompanied by vomiting. The abdomen was rigid; and two hypodermic injections of ¼ grain (0.016 gm.) of morphin gave no relief. A diagnosis of perforating duodenal ulcer was made. At operation, an acute perforating ulcer of the duodenum was found. The perforation was closed with silk sutures and a posterior gastro-enterostomy (Mayo) was performed. The patient was well Aug. 23, 1920, when he had a sudden seizure of severe abdominal pain in the region of the umbilicus. He vomited a brownish, foul material continuously. He was given enemas and a purge by his family physician without relief.

Examination.—This revealed rigidity of the muscles of the upper left abdominal quadrant and tenderness to the left of the umbilicus. A provisional diagnosis of acute obstruction was made.

Operation.—Through a high rectus incision the upper jejunum, just distal to the gastro-enterostomy, was found to have slipped back between the portion of the jejunum which had been left between the origin of the jejunum and the point where the gastro-enterostomy was made and the transverse mesocolon. The entire jejunum and more than half of the ileum had followed this loop through the opening. The bowel was in good condition and was not discolored. There was a small amount of bloody fluid in the abdominal cavity. The bowel was pulled back and a few sutures were placed between the mesentery, at the

origin of the jejunum and the transverse mesocolon, so as to close the opening. The patient's recovery was uneventful (Fig. 2).

CASE 3 (A 348789).—*History.*—Mr. A. M., aged 61, was examined Feb. 8, 1921. He had been operated on elsewhere in December, 1920, for hemorrhoids, and the diagnosis of cancer of the rectum was made. After the operation, there was less pain on defecation, but blood and mucus persisted.

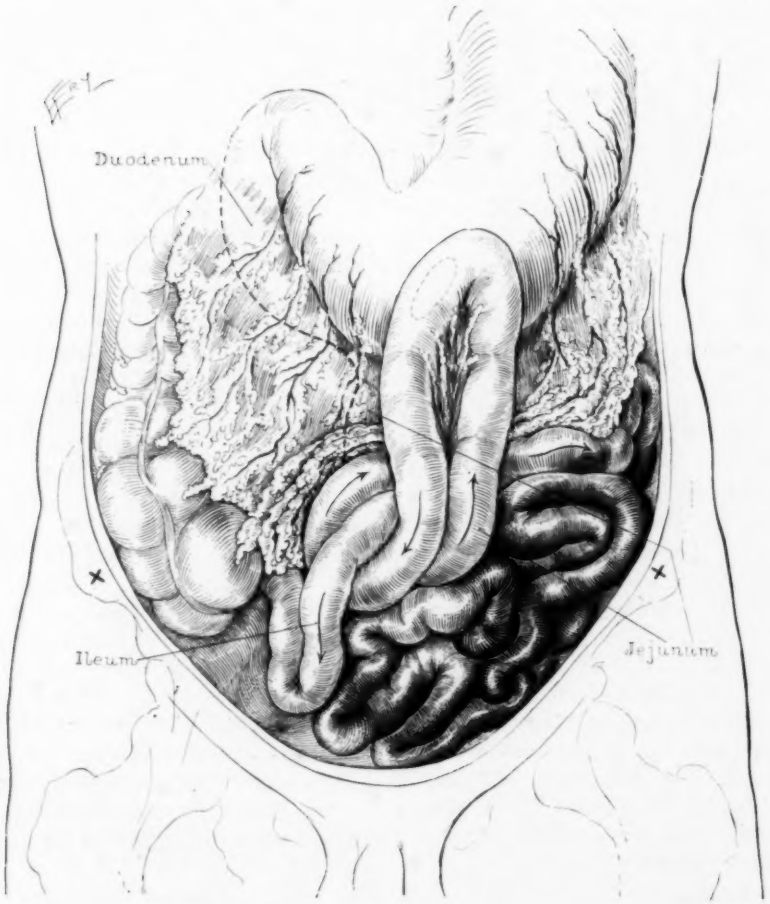

Fig. 1.—Hernia of the small intestine behind anastomotic loop of jejunum, following anterior gastrojejunostomy.

Examination.—The patient appeared to be fairly well nourished. The blood pressure was 154 systolic and 90 diastolic. The thyroid was enlarged. A large papillary mass appeared in the rectum. The urine showed a trace of albumin. Blood examination revealed: hemoglobin, 70 per cent.; erythrocytes, 4,500,000; leukocytes, 7,500. Roentgen-ray examination of the chest for metastasis was negative.

Operation and Result.—Feb. 17, 1921, a left rectus colostomy (Sistrunk method) was performed. The patient's convalescence was uninterrupted for six days, when his abdomen became markedly distended, especially on the left side. He passed very little gas and vomited greenish material several times. His pulse was 120, his temperature was subnormal.

A second operation was performed, February 26. The small intestine was greatly distended. The cecum and ascending colon were empty. Exploration

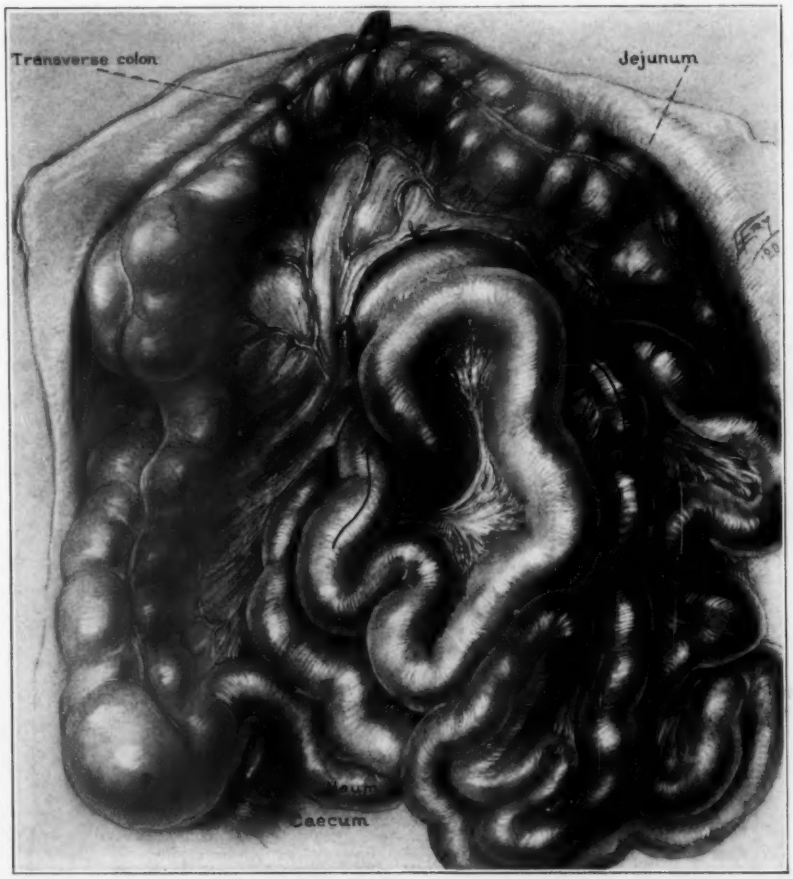

Fig. 2.—Hernia of the small intestine behind short anastomotic loop of jejunum following posterior gastrojejunostomy.

revealed that the entire small intestine had crawled completely around the colostomy (attachment of the sigmoid in the colostomy). The intestine, which was black, was reduced with difficulty and the abdominal wound was closed with through-and-through sutures. Color returned to the intestine after the reduction. Considerable free fluid was found in the peritoneal cavity. Following the operation, the patient was given an intravenous injection of 400 c.c. of saline solution. He failed to rally and died the same day (Fig. 3).

COMMENT

The symptoms from this type of internal hernia do not appear to differ from the usual symptoms of high intestinal obstruction of acute onset. The complication is more likely to occur in cases in which some form of chronic obstruction has distended and enlarged the loops of bowel.

To prevent this form of intra-abdominal hernia, Moschcowitz and Wilensky advised suturing together the margins of the opening, using

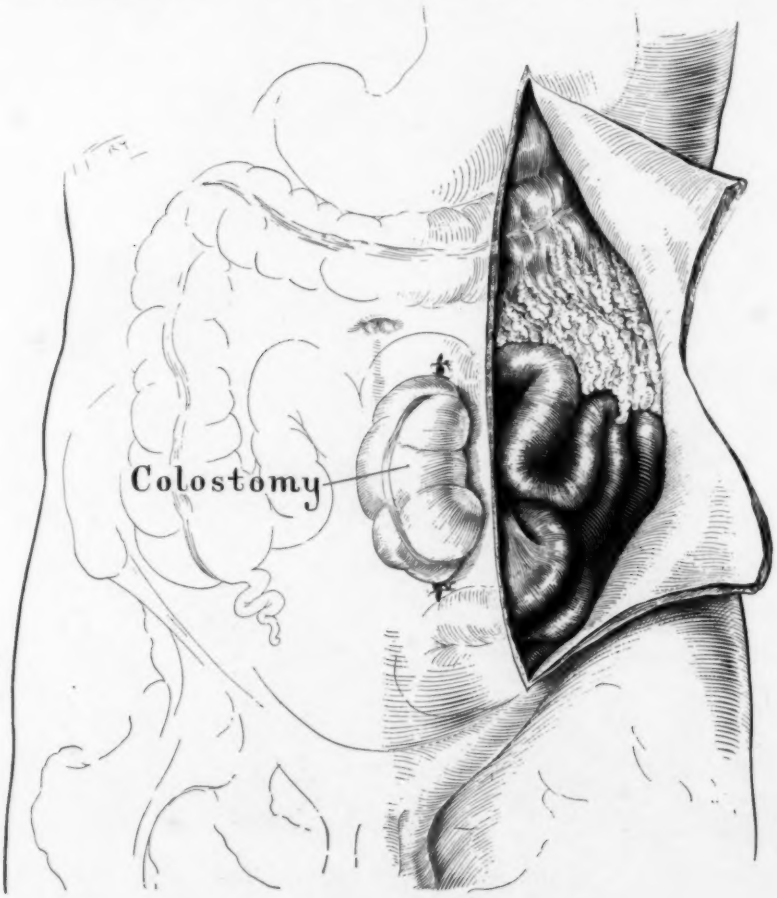

Fig. 3.—Hernia of the small intestine around colostomy.

the afferent loop of the jejunum and the inferior leaf of the mesentery. Bryan sutured the small intestine to the right lateral abdominal wall with several silk sutures. The latter method, however, should not be advocated. The practice followed in the clinic is described below:

In the anterior type of gastrojejunostomy, the abdominal toilet is carefully completed before the abdomen is closed. It is noted that no

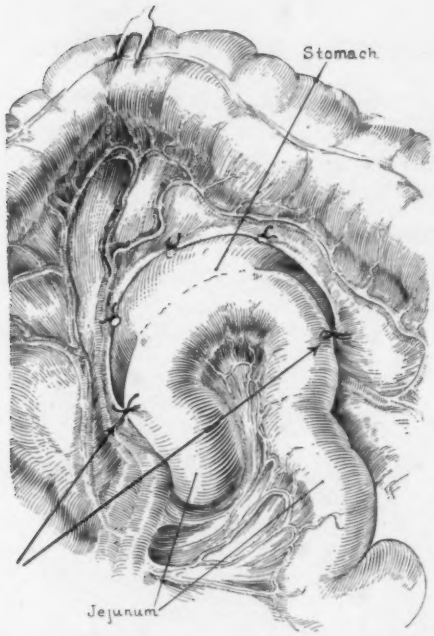

Fig. 4.—The arrows indicate the position of the sutures which would prevent the hernia shown in Figure 2.

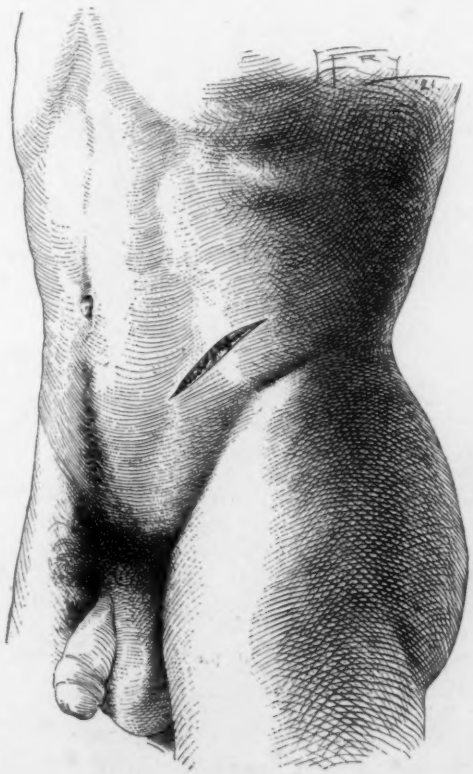

Fig. 5.—Incision for colostomy.

loop of bowel has passed behind the anastomosis either from right to left or from left to right. The omentum is placed around the loop of the anastomosis as securely as possible. Whether or not several sutures should be placed between the mesentery of the loop and the omentum is an open question.

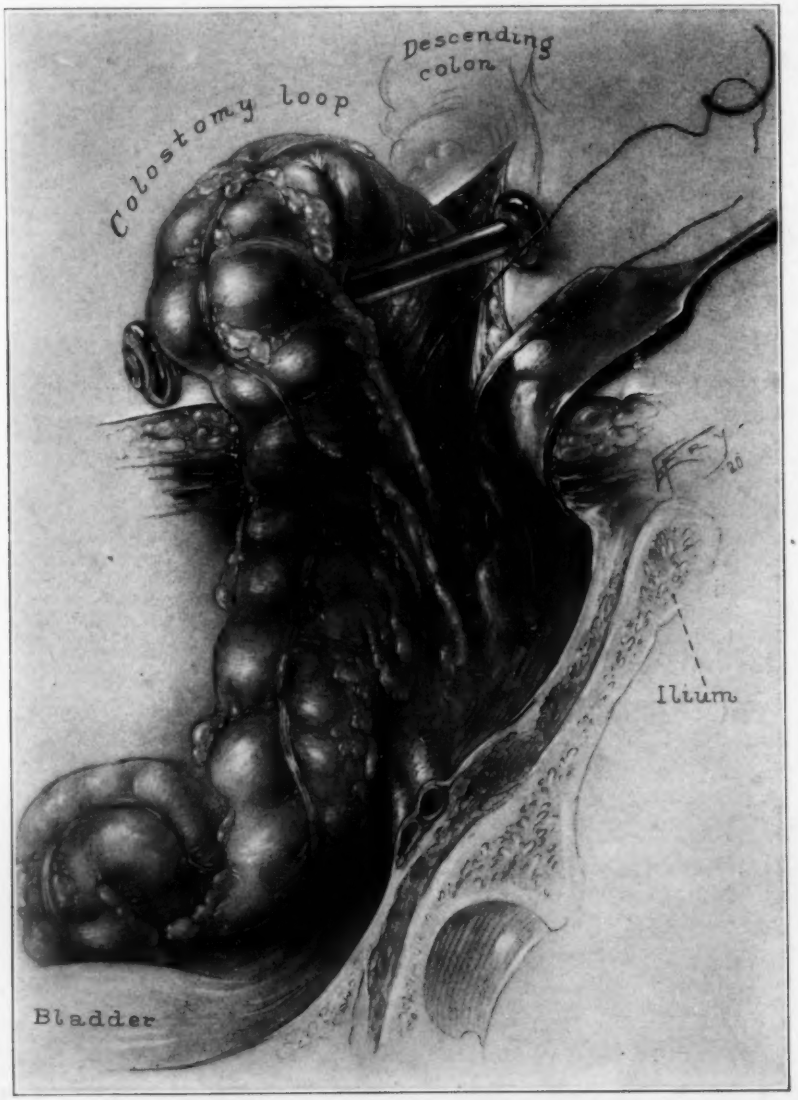

Fig. 6.—Continuous suture between parietal peritoneum and mesosigmoid, closing space on suture of colostomy.

In the retrocolic short loop gastrojejunostomy (the long loop retrocolic method is no longer performed), the space behind the anastomotic

loop through which herniation takes place is closed by placing a suture between the afferent loop and the transverse mesocolon on the stomach about 2.5 cm. above the gastrojejunal juncture, and another suture 2.5 cm. below (Fig. 4).

To prevent herniation following colostomy, the colostomy is made far to the left, on a line about one third of the distance between the left anterior superior spine and the umbilicus (Fig. 5). The Maydl-Littlewood type of colostomy is usually employed. After the loop of

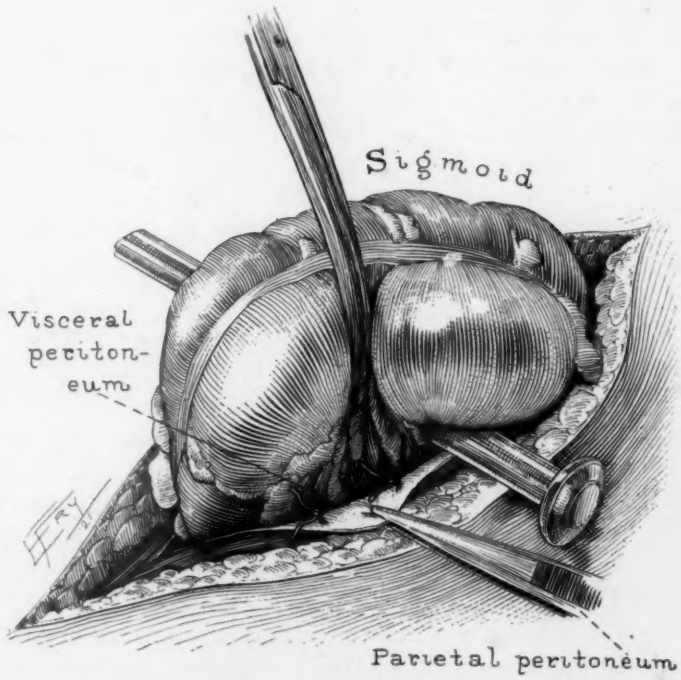

Fig. 7.—Two interrupted sutures through cut edge of parietal peritoneum and upper portion of mesosigmoid to prevent retraction of the colostomy loop.

sigmoid has been brought out of the abdomen, the mesosigmoid is sutured to the left parietal peritoneum by a continuous puckering suture (Fig. 6). Two interrupted sutures are then placed at the juncture of the sigmoid and its mesentery and just below the outer cut edge of peritoneum (Fig. 7). This procedure makes it impossible for the small intestine to pass around the colostomy, either from above or below. Such technic, especially if the small intestine is distended, tends to prevent postoperative complications, which, although rare, are extremely severe and result in a high mortality.

THE RADICAL CURE OF TUBERCULOSIS OF THE SEMINAL TRACT *

I. BRIEF SURVEY OF THE LITERATURE

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In a paper which I presented three years ago ("Presentation of a Radical Operation for Tuberculosis of the Seminal Tract"), I discussed at some length the operative treatment of genital tuberculosis. I referred to the fact that beginning with the first seminal vesiculectomy by Ullmann in 1889 reports of thirty-two cases were to be found in the literature during the next twelve years; but the results which were obtained by the various technics employed were so unsuccessful that I was forced to the conclusion that the radical operation for tuberculosis of seminal vesicles should be abandoned. A further review of the literature showed that the testicle was rarely involved, except late in the disease, and that epididymectomy gave as radical results as castration. Von Bügner's plan of injecting the vas with glycerin containing iodoform was approved; but his plan of forcible evulsion of the vas was shown to be bad by published reports of cases in which both fatal infections and hemorrhages had occurred. I proposed a new method of permanent drainage of the deeper tract, by bringing the upper end of the vas deferens out through the upper end of the wound in the groin, where I advised that it be subsequently injected with oil containing iodoform or phenol, which I also employed.[1]

Following this paper, Belfield added great interest to the question of treating the seminal vesicles and ampullae by vasostomy in cases of chronic infection, and in 1909 Cunningham [2] brought up again the question of treatment of tuberculosis of the seminal vesicles by means of injection of phenol through the vas deferens, reporting thirty-four cases in which good results were obtained by this procedure. In my recent paper,[3] in 1918, I called attention to the fact, that, at my clinic, studies of the cases as years passed by showed that whereas many good surgical results were obtained by removal of the external focus (epididymectomy or castration), in many other cases very unsuccessful results were obtained, many of the patients dying in great misery from tuberculosis, urogenital or generalized.

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* From the Brady Urological Institute and the Johns Hopkins Hospital.

1. Legueu: Traité chirurgicale d'urologie, 1910.
2. Cunningham. J. H., Jr.: Surg., Gynec. & Obst. **23**:385 (Oct.) 1916.
3. Young, H. H.: Surg., Gynec. & Obst. **26**:375 (April) 1918.

I, therefore, urged the adoption of a radical operation for tuberculosis of the seminal vesicles and presented a simplified method which I had carried out with a special, delicate, long tractor, which can be introduced through the penile urethra into the bladder and which greatly facilitates successful removal of the entire tract.

This article has called forth objections from many of my friends who are urologists; but believing that the time is now ripe for reopening the question and for a thorough study of the problem, both from a pathologic and a clinical standpoint, and especially as to the results obtained, I am, therefore, again presenting these most important questions: What is the primary seat of infection, its mode of progression to other organs, and the appropriate operation in genital tuberculosis?

Turning to the French literature, I find that Guyon,[4] the father of modern urology, stated many years ago that the tuberculous process begins generally in the seminal vesicles. He cited twenty-six necropsies in which the seminal vesicles were found to be primarily the site of disease; in two cases only the seminal vesicles were involved and in ten cases the prostate was infected simultaneously with the vesicles. In one case, the prostate alone was involved. In 220 clinical observations of patients suffering from urogenital tuberculosis which Guyon examined personally, forty cases were isolated genital tuberculosis, seventy-four were cases of tuberculosis of the urinary organs and 108 were combined urinary and genital tuberculosis. In 127 clinical cases in boys suffering from urogenital tuberculosis before the age of puberty, Guyon found the prostate involved in fifty-six, prostate and seminal vesicles in eleven, epididymides twice and all of the genital organs fifty-eight times. Guyon asserted his belief that the tuberculous process begins most frequently in the seminal vesicles and that the involvement was from within outward, toward the external genitalia.

Guelliot[5] reported that in fifty-nine cases of tuberculosis of the seminal vesicles the lungs were involved in forty-nine, the prostate in thirty-six, the testicle and epididymis in thirty-four and the bladder and urethra in twenty-nine.

More recently, Legueu[1] stated his preference for epididymectomy in unilateral cases, but he believed that in cases in which the vesicles are involved and in bilateral epididymal infections the entire seminal tract should be removed. He believed that such operations were not contraindicated by involvement of the bladder or even of the lungs.

At the Thirtieth Congress of the German Surgical Association, the subject of tuberculosis of the seminal tract was thoroughly discussed.

4. Guyon, cited by Walker, MacFarland: Lancet **1**:435 (Feb. 15) 1913.
5. Guelliot: Presse méd. **33**: 1898.

Bruns reported 111 cases, in seventy-eight of which unilateral castration had been performed and in thirty-three double castration. A study of these unilateral castration cases showed that the second testicle was involved in 34 per cent. of the cases in three months; in 40 per cent. in four months, and in 60 per cent. in the later cases. He stated that in the seventy-eight cases in which unilateral castration had been performed, the other testicle became involved in 26 per cent. of the cases. As to results obtained by castration, his statistics showed that after unilateral castration only 45 per cent. of the patients were cured and after bilateral castration only 56 per cent.

Simon stated that in 107 cases, sixty-one remained cured after castration (57 per cent.). Koenig, who opposed this operation, advised, in the treatment of tuberculosis of the epididymis and testicle, "vesiculoprostatic resection, the best means of access for which consists in osteoplastic resection of the sacrum, the last piece of the sacrum and coccyx, being included in the flap." He gave no figures regarding results.

Boguljüboff [6] reported 166 cases with tuberculosis of the epididymis or testicle and stated that in 137 cases the other side became tuberculous within an average time of fourteen months.

Berger [7] gives the results in forty-seven cases which were followed over a period of from one to twenty-five years (Table 1).

TABLE 1.—Results in Forty-Seven Cases

	Number	Now Apparently Well	Stationary	Dead	Dead, per Cent.
1. Not operated	1	0	—	1	100
2. Resection of epididymis	3	3	—	—	0
3. Single castration	34	20	4	10	29
4. Double castration	9	6	—	3	33
Total	47	..	..	14	29

Berger asserts that of the forty-three single or double castration cases, twenty-six patients (60.4 per cent.) are well up to the present, but some have been followed only two years or less.

In England, Thompson Walker [8] presented a study of 100 cases of genital tuberculosis in fifty of which the genital organs were involved, in thirty-seven the genital and urinary organs, and in thirteen there was genital or other tuberculosis (lung, etc.). Of the 100 cases, the epididymis was affected in seventy-two; in sixteen the prostate and seminal vesicles were also involved; in fourteen the seminal vesicles, and in sixteen the prostate alone, was involved. We have, therefore,

6. Boguljüboff, cited by Whiteside, G. S.: Northwest Med. **18**:83 (May) 1919.

7. Berger: Arch. f. klin. chir. **68**:915, 1902.

8. Walker, Thompson: Surgical Diseases and Injuries of the Genito-Urinary Organs, London, Cassell & Co., 1914.

forty-six cases, out of seventy-two (64 per cent.), in which the region of the prostate and vesicles was involved. He believes that the infection may reach the epididymis by the blood stream and also by the vasa deferentia. Thompson Walker also states that tuberculosis of the epididymis invariably involves the second epididymis after a year or more. He concludes:

> My practice is to treat chronic tuberculosis with tuberculin and to limit operative procedures to opening and scraping abscesses when they arise. Such treatment must invariably lead to chronic discharging sinuses. If the disease appears to be spreading in spite of the tuberculin treatment, epididymectomy is performed and if it is already very extensive and has involved the testicle, this organ is removed. I have not found it necessary to perform extensive operations for the removal of the pelvic portion of the vas deferens.

In a remarkable article, "The Paths of Infection in Genito-Urinary Tuberculosis," MacFarland Walker,[4] in 1913, presented the most careful historical, clinical and experimental study of genital tuberculosis. He states that, in a series of twenty-two cases of tuberculous epididymitis, involvement of the prostate and vesicles was discovered in twenty. Of the two exceptions one was that of a baby of 15 months and the other a boy who had undergone bilateral castration at the age of 14. Walker says that "in every one of these cases the first signs of disease were detected in the lower pole of the epididymis;" and that at the lower pole, the first signs of softening and breaking down are observed.

> That the lower pole of the epididymis should be the commonest site of the primary deposits is only to be expected, if the tuberculous infection is a descending one. It is the first spot to be reached by the infective agent in its journey down the cord. The tuberculous testicle falls into the same category as a gonococcal one, and if we are prepared to admit a descending infection in the case of the gonococcus, we cannot rationally deny it in the case of the bacillus of tuberculosis.

Walker then details the experiments which he carried out with various bacteria. In one, he inoculated the anterior urethra of guinea-pigs with organisms; and, after twelve hours, abundant growth was obtained from the epididymis and a much scantier one from the testis. The same organisms were found in the vesicles and in the plexus of the lymphatics, running with the vas. A control cultivation of the blood gave a negative result. Microscopic sections of the tissues in these cases show the presence of numerous organisms in the lymphatics, surrounding the vas. In the lumen of the vas itself, few or no organisms were found.

> Baumgartner's failure to produce a descending tuberculosis experimentally in rabbits is, in my opinion, no proof of any inability on the part of the tubercle bacillus to descend the cord, in a direction contrary to the secretions.

The inoculation of the urethra or even of the cord is insufficient; it is necessary also to prepare the testicle for the reception of the tubercle bacillus by previously injuring it.

Walker says that he inoculated the rabbit's urethra and exposed the left testicle to a certain amount of trauma. At the end of six weeks the epididymis was indurated and swollen on the injured side. Necropsy revealed tuberculosis of the epididymis and seminal vesicle, and microscopic examination showed tuberculosis in the epididymis but none in the body of the testicle.

The possibility of the lymphatics of the cord acting as the path along which a descending infection of the testicle may advance is supported to some extent by the appearance of specimens obtained from the postmortem room. The prostatic and the testicular extremities of the cord are markedly affected, while the intervening portion appears healthy. If transverse sections are made and examined microscopically, the following is found to be the exact distribution of the tuberculous lesions. Transverse sections of the prostatic extremity show that the vas itself is comparatively healthy but that it is surrounded by a thick shell of tuberculous tissue, due to infiltration of the lymphatics. As the testis is approached, this lymphatic infiltration gradually ceases. A section of the distal end of the vas, near its termination in the epididymis, shows a converse condition. Here the disease has affected the mucosa of the vas, whereas the surrounding lymphatics give little or no evidence of any lesion. This distribution suggests that the disease is disseminated from the prostate, by the lymphatics, and that having encountered in the epididymis a suitable soil in which to flourish, it produces a returning wave of infection in the vas through the agency of the secretions. It is interesting to note that microscopic examination of genital tuberculosis experimentally produced in the rabbit by urethral inoculation shows an exactly similar distribution. The prostatic extremity of the vas and the seminal vesicle on the diseased side were enclosed in a dense shell of tuberculous infiltration, the inner coat of the vas being healthy.

Apart, therefore, from other considerations, the distribution of the tuberculous tissues alone suggests the existence in these cases of two opposing waves of infection, a centrifugal and primary one, traveling from the prostate along the lymphatics; a centripetal and secondary one, in the lumen of the vas, due to the flow of infected secretions from the diseased epididymis.

From a consideration of the foregoing, it would appear that infection of the testicle (i. e., epididymis) takes place in tuberculosis, as in gonorrhea, by means of the cord and not by the blood stream. That cases of hematogenous infection occur cannot be denied, but they are few in number. The evidence in favor of the frequent occurrence of a descending genital tuberculosis may be tabulated thus:

Clinical Evidence: 1. It is extremely rare to find tuberculosis of the epididymis without discovering some indication of disease of the prostate or the vesicle. 2. Prostatic tuberculosis is not infrequently found without any lesions of the testicle. 3. The appearance of a tuberculous epididymitis is often preceded by symptoms of prostatitis or vesiculitis, the so-called prodromata of tuberculous epididymitis. 4. The earliest signs of tuberculous disease are found at the lower pole of the epididymis. This is the first position which opposes the line of march of the invading organisms. 5. Tuberculous disease of the

testicle is analogous to acute infections which are known to have been produced by extension from the urethra. The ordinary type of tuberculous epididymitis has no analogy to the hematogenous orchitis of mumps.

Pathologic Evidence: 1. Lesions of the testicle without disease of the prostate are rare; whereas tuberculous lesions of the prostate are not infrequently found unaccompanied by disease of the testicle. 2. When tuberculosis of the testicle is found in association with tuberculosis of the prostate, the lesions in the prostate generally appear to be older than the lesions in the epididymis. 3. Tuberculous nodules in the lower pole of the epididymis usually appear older than those in the upper pole. They are the first to soften and break down.

Experimental Evidence: 1. Micro-organisms and inanimate granules are rapidly absorbed from the urethra and carried to the testicle. 2. A tuberculous epididymitis may be experimentally obtained by inoculating the urethra after having damaged one of the testicles.

The experiments of MacFarland Walker are of utmost importance in that they show the futility of hoping *completely* to eradicate the disease by epididymectomy or castration.

A brief report of some of the most important articles in the American literature is of interest.

In 1907, E. L. Keyes, Jr.,[9] presented a careful study of 100 patients with tuberculosis of the testicle, fifty-three of the cases being bilateral. Speaking of the site of the first infection, he says:

> In only twenty-five cases was I able to obtain information on this point and yet in nineteen of them the nodule appeared in the tail of the epididymis and in only six did it begin in the head.

In eighty-seven cases, Keyes says that the opposite testicle was affected in fifty-three cases, and that in thirty-four it was affected when the patient was last seen. In ten patients in whom the testicle was involved at the time of operation, three relapses on the opposite side occurred within one year; two after one year and two more after two years, making seven relapses in all, while of the remaining three patients in whom the opposite testicle was not known to be involved, two were followed less than a year and one followed for two years.

> Further evidence of the futility of attempting amputation of tuberculosis is the involvement of the other organs in two years, in unilateral orchidectomy, one case of urethral abscess, one of vesicular abscess, two of tuberculous kidney, one of acute prostatitis, and one of tuberculous inguinal adenitis. Such results simply confirm the belief that, though apparently localized in the testicle or elsewhere in the body, tuberculosis is a disseminated infection which cannot be amputated.

Keyes draws the following conclusions:

> Testicular tuberculosis is never an isolated lesion. Relapses in the opposite testicle occur within a few years in eight or nine out of ten cases. Be the operation ever so slight or ever so radical, relapses on the opposite side almost inevitably occur.

9. Keyes, E. L., Jr.: Ann. Surg. **45**:918, 1907.

In a series of important studies on genito-urinary tuberculosis, Barney [10] brings forth similar testimony. He states that in 821 cases in which the condition of the prostate and seminal vesicles were described, 75 per cent. were tuberculous. In 101 rectal examinations, in Barney's own series of cases of genital tuberculosis, seventy-six revealed tuberculosis of the prostate and seminal vesicles.

Barney states he has traced 113 patients with tuberculosis of the epididymis from one to twenty-five years after operation and that 27 per cent. of them died of some form of tuberculosis.

> Eighty-one per cent. of these examined and 28.5 per cent. of those reached only by letter are still within the six-year period, and it is to be expected that the deaths from tuberculosis are not yet at an end.

Barney makes this very strong statement:

> I have already pointed out the disastrous results of genital tuberculosis and the rapidity of recurrence. It has been shown that the second epididymis is attacked in 26.5 per cent. within the first six months after the involvement of the first side; that the disease invades prostate and vesicles in 30 per cent. within the same time; and that testicular tuberculosis within this period is found in 60.6 per cent. If one adds to this misfortune, the annoyance of bladder irritability and the affliction of sterility, the outlook is indeed gloomy. It is also to be remembered that a very large proportion of patients have the proverbial ax hanging over them in the form of tuberculosis of other organs.

In an interesting paper, in 1910, Whiteside [11] called attention to the fearful ravages of testicular tuberculosis and ineffectiveness of resection of the epididymis. He stated that from necropsies and from his own clinical experience, he believed involvement of the entire genital tract to be frequent and that epididymectomy was entirely inadequate. He stated that he had recently practiced a radical operation in such cases and cited the case of a man in a deplorable condition with involvement of both testicles, epididymides, prostate, seminal vesicles and bladder, in which a wonderfully satisfactory result was obtained by extirpation of the seminal vesicles as well as the external foci of involvement. Whiteside [12] has recently published another article on this subject, reciting several remarkable results in apparently desperate cases and calling attention to the value of a radical operation. In response to a personal letter of inquiry, he states that he is unable to get exact statistics of the number of cases or results, but he says:

> My remote results, quoting from memory, are that those patients who have survived are well. They even tell me that they are sexually able to perform

10. Barney, in Cabot, Hugh: Modern Urology, Philadelphia, Lea & Febiger, 1918.

11. Whiteside, G. S.: California State J. M. **8**:88, 1910.

12. Whiteside, G. S.: Northwest Med. **18**:83 (May) 1919.

coitus. Those with good resistance to the disease have complete healing of all operative wounds and resultant sinuses before six months after operation. Those that are tuberculous elsewhere than in the genital tract have one or more sinuses in the perineum or groins for a year or more. These cases for which I advocate radical removal of everything tuberculous are advanced cases. Consequently, a large percentage of these have, or soon suffer from, further tuberculosis (lungs, kidneys, etc.) and many died within five years after operation.

Cunningham [2] states that of eighty-six patients showing tuberculous epididymitis forty-nine showed lesions of the prostate or vesicles. Cystoscopy was carried out in fifty-one of these eighty-six cases and showed tuberculosis of the bladder in sixteen, in nine of which one kidney was tuberculous and in five both kidneys were involved. Sixty-seven had distinct signs in the lungs.

Cunningham [2] says (p. 388):

> Barney's report, the most recent and complete in regard to end-results, showing a mortality of 85 per cent. within six years following such procedures (epididymectomy and castration) in an institution of the highest surgical efficiency, is far from satisfactory.

He then recommends the plan of von Büngner, of injecting the vas after epididymectomy, advising the use of pure phenol, and reports the cases of thirty-two patients thus treated, namely:

Of these thirty-two patients, seven, or 21.7 per cent., have died in ten years; twenty-five, or 88.3 per cent., are living; four have demonstrable tuberculosis in the genito-urinary tract; one has no demonstrable tuberculosis, but the inoculation test is positive; twenty, or 62.5 per cent., are locally free from the disease.

Following my paper [3] in 1918, there appeared an excellent article by Quinby [13] in which he reported seven cases in which operation was performed by a technic similar to that described by me, with excellent results.

II. STUDY OF CASES AT JOHNS HOPKINS HOSPITAL

A. In order to see what our own statistics show with regard to the various questions which have been brought up in this study of the pathology and surgical treatment of tuberculosis of the seminal tract, I have examined the records of eighty-six cases of genital tuberculosis in the general surgical department of Johns Hopkins Hospital. The operations performed on these patients were:

Castration: right, twenty-four, of which four had left epididymectomy, and one had previous right epididymectomy; left, twenty-nine, of which three had right epididymectomy, and there is no record of

13. Quinby, W. C.: Genital Tuberculosis, J. A. M. A. **71**:1790 (Nov. 30) 1918.

previous left epididymectomies; both, five. Epididymectomy: right, ten, of which one had right castration and three had left castration subsequently; left, six, of which four had right castration; right and left, five, with no note of castration subsequently. Nephrectomy, three. Perineal section, one. Suprapubic cystotomy, one, and no operation, fifteen.

I have been unable to secure sufficient replies from these patients to determine the results which have been obtained by the treatment which was given. Most of these patients were operated on a long time ago, before the operation of epididymectomy had been introduced into this hospital, and as a result, castration was more often employed. I have searched the pathologic records and found satisfactory pathologic reports as follows: Castrations, twenty-seven. In all of these the testicle, epididymis, vas and part of the cord had been removed. Gross and microscopic examination demonstrated tuberculosis of the epididymis in all of these cases and in twenty cases also tuberculosis of the testicle. In seven cases the testicle was reported to be uninvolved, although the epididymis was markedly tuberculous. Only two of these cases were bilateral.

B. I have next analyzed sixty-six cases of tuberculosis of the epididymis in patients who have presented themselves at my private clinic and which have been carefully studied by Dr. R. S. Young. The totals are as follows:

(*a*) *Involvement According to Clinical Examination.*—Epididymis: right 16, left 17, both 23, total 56; testis: right 7, left 4, both 0, total 11; vas: right 2, left 1, both 3, total 6; vesicles: right 6, left 1, both 11, total 18; prostate: 14; bladder: 24; kidney: right 5, left 11, both 2, total 18.

(*b*) *Operations Performed.*—No operation: 10; castration: right 7, left 10, both 0, total 17; epididymectomy: right 10, left 12, both 10, total 32; vasectomy: 1; suprapubic cystotomy: 0; nephrectomy: right 3, left 8, total 11.

(*c*) *Subsequent Operations.*—Castration: total 2; epididymectomy: double 1, single 2, total 3; nephrectomy: total 2; abscess of groin: total 2; suprapubic cystotomy: total 1; abscess of perineum: total 1.

(*d*) *Ultimate Results (Sixty-Three Cases).*—No information: 18; well: 8; improved: 14; not improved: 2; worse: 3.

Length of Time Followed Since Operation.—Under one year 2; between one and two years 7; two years 4; three years 2; four years 3; five years 1; six years 2; eight years 1; nine years 1; twelve years 1.

Fatal Cases.—Eighteen (not included in above dates).

Interval Between Admission and Date of Death.—In hospital 3, less than one year 6; one year 1; two years 2; three years 1; not stated 3.

Among fatal cases, no operation was performed in two cases.

C. Further analysis of cases (operative):

Region Involved.—Right epididymis 16, epididymectomy 10; no subsequent operations. Left epididymis 17, epididymectomy 12. Of these one required right epididymectomy two years later, a second required right nephrectomy for tuberculosis seven years later and developed tuberculosis of the left kidney six years later, a third underwent a right nephrectomy for tuberculosis one year previously and a fourth submitted to right castration one year previously. Both the right and the left epididymis were involved in twenty-three cases; double epididymectomy in ten. Of these one required left castration four and one-half months later, a second required castration three years later.

Region Involved.—Right kidney 5, nephrectomy 3; no subsequent operations. Left kidney 11, nephrectomy 8. Of these, 1 required left epididymectomy four months later, 2 others required double epididymectomy five and two months later.

D. Cases of bilateral involvement of the epididymides:

Region Involved.—Number of cases 23. Of these cases, the second epididymis involved was: (*a*) globus minor of second epididymis involved without any, or very little, involvement of the globus major 9; (*b*) globus major involved in second without any, or very little, involvement of globus minor 1; (*c*) both markedly involved, so that primary site in epididymis could not be told 9, and (*d*) history not clear in 4.

E. Cases complicated with: tuberculosis of kidney, 4; globus minor involved, 3; globus major involved, 0; and entire epididymis involved, 1.

In cases of tuberculosis of the epididymis with tuberculosis of the seminal vesicles and prostate: globus minor involved, 12; globus major involved, 3, and entire epididymis involved, 21.

F. An analysis of the cases of: one-sided epididymal tuberculosis in which there was no prostatic or seminal vesicle involvement made out, 10: according to history: swelling or pain began at upper end, 1; swelling or pain began at lower end, 2, and not determined, 7. At examination: involvement only of globus minor, 4; involvement only of globus major, 0, and involvement of entire epididymis, 6. At operation: involvement only of globus minor, 2; involvement only of globus major, 0, and involvement of entire epididymis, 4.

G. These statistics show conclusively the absence of isolated testicular tuberculosis and the rarity of testicular involvement when the epididymides are extensively involved. What is the point of primary involvement in the epididymides? Table 6 seems to show that even without discoverable involvement of vesicles and prostate, the globus minor is more often the point of primary involvement in the epididymis.

Table 5 seems to show very conclusively that when the opposite epididymis becomes involved, it is generally the globus minor which is first involved. This is also true in cases of epididymitis in which the vesicles were found to be involved on rectal examination. Can we not justly draw the deduction that in almost all cases the primary focus in genital tuberculosis is the seminal vesicle? The prostate is definitely shown to be very rarely the primary seat of involvement.

H. In another study of seventeen cases of castration, all were found to be tuberculous. No cases were found in which normal testes were removed. In one case of double epididymectomy, right castration was performed three years later (elsewhere).

Résumé.—Of 63 patients, 53 were operated on. Of these 18 are dead. Eighteen have not been heard from, and of the 45 patients heard from 13 have been operated on less than three years and 9 less than two years. There remain, therefore, out of 63 patients, only 27 who are known to be or have been alive three years or more since admission. Of these, only 22 are known to be well and improved. When we consider also that, with the exception of about 24 cases, the urinary tract was not involved and that the cases were, therefore, fairly early cases of tuberculosis of the seminal tract, the results obtained by epididymectomy or castration are, indeed, very poor. In many of these cases, the seminal vesicles were injected through the vas from one to four times during and after operation, either oil containing iodoform or pure phenol being employed.

I. Analysis of 28 cases of urogenital tuberculosis without involvement of epididymides or testicles. *Region Involved* (as made out at examination).—Prostate, 26; seminal vesicles: right 1, left 1, both 14, total 14; bladder: 16; kidney: right 2, left 2, both 1, total 5.

Previous Operations Performed.—Nephrectomy: right 2, left 1, total 3; suprapubic cystotomy: total 1. No operation on prostate or vesicles in any of these cases.

Results.—Only one of these patients is said to be well. He had tuberculosis of the prostate, bladder and both seminal vesicles and no operation was performed. Seven years have elapsed since he was here. He has not been examined personally. Four are said to be improved and have been followed six, seven, eight, and thirteen years, respectively. In all of these 4 the prostate was involved, in 2 the seminal vesicles, and in 2 the bladder. The kidney was involved in 1 case, and in the latter case nephrectomy was performed. In the other 3 cases no operation was performed. Repeated questionnaires have been sent out and 5 patients are known to have died. In 18 cases, no information can be obtained and it is probable that in many of these the patient has died.

Comment.—This is another melancholy record resulting from the nonoperative treatment of tuberculosis of the seminal vesicles and prostate.

III. ANALYSIS OF STATISTICS TAKEN FROM THE LITERATURE AND FROM OUR OWN SERIES OF CASES

Certain clinical and pathologic statistics taken from the literature are presented herewith in tabulated form to which we have added similar statistics from our own cases, the sixty-three mentioned before in B.

TABLE 2.—TUBERCULOSIS OF EPIDIDYMIS

	Number of Cases	Prostate or Vesicles Involved, per Cent.
Thompson Walker	72	64
MacFarland Walker	22	91
Barney	100	77
Cunningham	86	57
Young	55	60

Comment.—These statistics are sufficient to demonstrate that among patients presenting evidence of tuberculosis of the external genitalia more than 50 per cent. present definite evidence of involvement of the prostate or vesicles, or both. In view of the fact that early lesions in the vesicles are difficult to prove, we feel that the statistics of Barney and possibly of MacFarland Walker give more nearly the correct percentage. Among my cases, thirty are unilateral, which is additional confirmatory evidence that the seminal vesicles became involved early in testicular disease, if not preceding it. As a matter of fact, all statistics, and particularly those of MacFarland Walker, indicate that the seminal vesicles are the primary site of disease in a great majority of cases of tuberculosis of the epididymis.

TABLE 3.—PERCENTAGE OF BILATERAL INVOLVEMENT OF THE EPIDIDYMIDES OR TESTICLES IN CASES OF TUBERCULOSIS OF THE EPIDIDYMIS OR TESTICLE

Author	Cases	Bilateral	Percentage
Keyes	100	53	53
Bruns	111	42	38
Bogoljüboff	166	137	82
Berger	43	9	20
Barney	150	60	40
Koenig	...	..	75
Young	78	28	36

The figures in Table 3 simply confirm what has already been indicated: the great frequency of bilateral testicular or epididymal involvement and the frequency of simultaneous involvement of the seminal vesicles.

Table 4 is further proof that after removal of the disease on one side there remains a tuberculosis of the seminal vesicles from which the other testicle becomes involved, another argument showing the inadequacy of unilateral epididymectomy or castration.

TABLE 4.—Involvement of the Second Testicle After Operation

Author	Cases	Opposite Side Involved, per Cent.
Bruns	78	26
Keyes	87	53
Barney	106	15

We have next collected the statistics as regards cures which have been effected by castration or epididymectomy. In most instances, it is not possible to determine whether a single or double operation was performed, nor have the epididymectomies been separated from the castrations. There is also considerable variation as to what is considered a cure—a cure of the lesion in the scrotum is quite different from the entire disappearance of the disease from the whole genital tract. In my statistics I have included in Table 5 also cases of patients that were improved. If cures only were included, the percentage would be only 19 per cent.

TABLE 5.—Percentage of Cures Obtained by Castration or Epididymectomy

Author	Number of Cases	Unilateral Castration or Epididymectomy, per Cent.	Bilateral Castration or Epididymectomy, per Cent.	Bilaterality Not Specified, per Cent.
Bruns	111	45	56	
Berger	47	55	66	
Simon	107	..	..	57
Barney	113	..	..	73
Cunningham	32	..	..	62
Young	42	..	..	45

These statistics are proof of the ineffectiveness of castration or epididymectomy. Barney's words are most significant:

> Let us now see what encouragement can be held out to the patient with tuberculosis of the epididymis (by epididymectomy). I have traced 113 patients from one to twenty-five years after operation. Over 27 per cent. have died of tuberculosis. Within the period of six years after operation 41 per cent. of fifty-eight patients have died of this disease. Eighty-one per cent. of those examined and 28 per cent. of those reached by letter are still within the six-year period in which I have found that 85 per cent. of deaths occurred. It is to be expected that tuberculosis in this group is not yet at an end.

In order to determine the relationship between cure and the previous presence of tuberculosis of the prostate and vesicles, I have carefully

searched the records of our cases of epididymectomy and castration with the results given in Table 6.

TABLE 6.—Cases of Epididymectomy or Castration in Which the Patient Is Reported as Well or Improved*

	Number of Cases	Prostate Involved	Seminal Vesicles Involved	Both Involved	No Involvement
Well	8	1	0	2	5
Improved	14	2	2	4	6
Dead	18	..	..	7	3

* Dead: Prostate and bladder, 1; vesicles and bladder, 1; vesicles, prostate and bladder, 2; kidney, 1; kidney and vesicles, 1; bladder, 1; bladder and kidney, 1.

Analyzing these tables, we see that in the cases of the patients that recovered 5 out of eight had no evident involvement of vesicles and in those that were recorded as improved there was no involvement in six out of fourteen, showing conclusively that a large percentage of the few good results from epididymectomy or castration are among those early or isolated cases in which the involvement of the prostate and seminal vesicles is either absent or too small to be detected, and the fact that among those patients who are reported dead only three out of eighteen have no involvement of the deeper structures is also strong evidence that the more radical operation should have been carried out in those cases.

Résumé of Argument.—The preceding statistics seem, therefore, to show conclusively that in the great majority of cases the primary involvement is in the seminal vesicles (or prostate), from which the epididymides or testicles are subsequently involved, the external disease being bilateral in from 30 to 50 per cent. of the cases. In a probably larger percentage of the cases, the involvement of the seminal vesicles is bilateral (61 per cent. of my cases in series B and probably higher). The disease reaches the epididymis generally by the lymphatics of the cord from the seminal vesicles and first involves generally the globus minor. It is probably erroneous to suppose that primary tuberculosis of the epididymis often occurs. It probably seldom occurs through blood stream infections, as so often asserted. The seminal vesicles are not only the primary focus from which the epididymides are involved, but from which also the prostate, bladder and the kidneys in many cases are involved. In fact, tuberculosis in the region of the prostate and vesicles is far more dangerous to the entire human organism than tuberculosis of the epididymides and is probably responsible for the fearful mortality which is variously estimated at from 27 to 60 per cent. in cases of genital tuberculosis. Therefore, it is the duty of the surgeon to attack the most dangerous focus of involvement, namely, that of the vesicles and prostate. Therefore, in tuber-

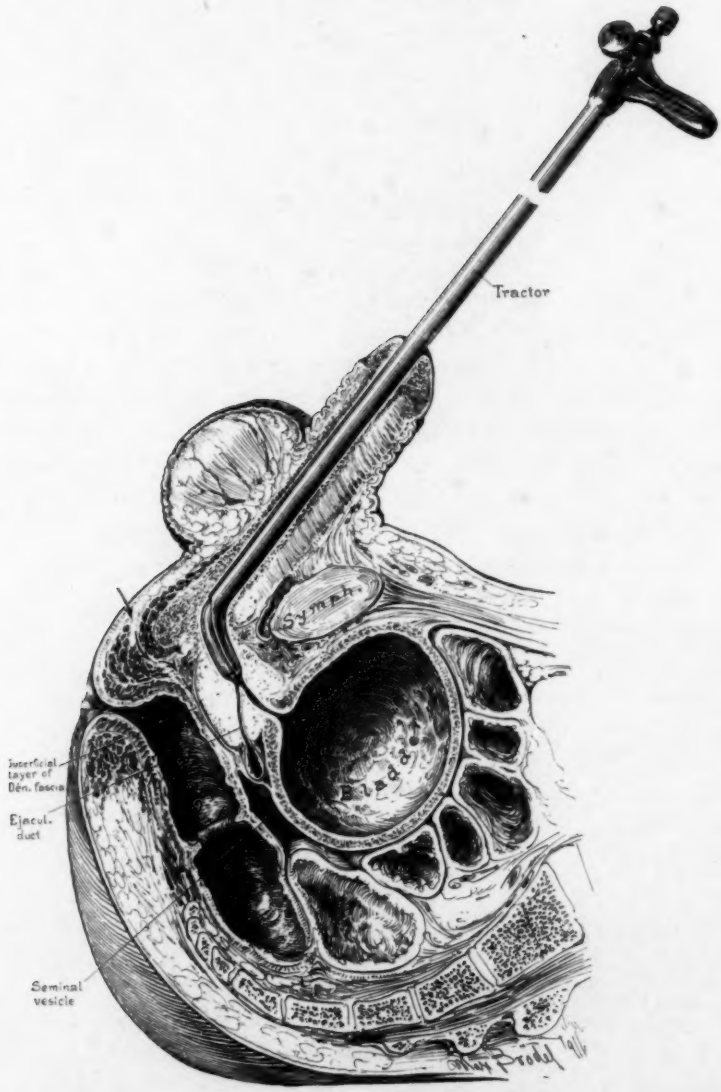

Fig. 1.—Anatomy of the region, arrows indicating route; tractor in urethra.

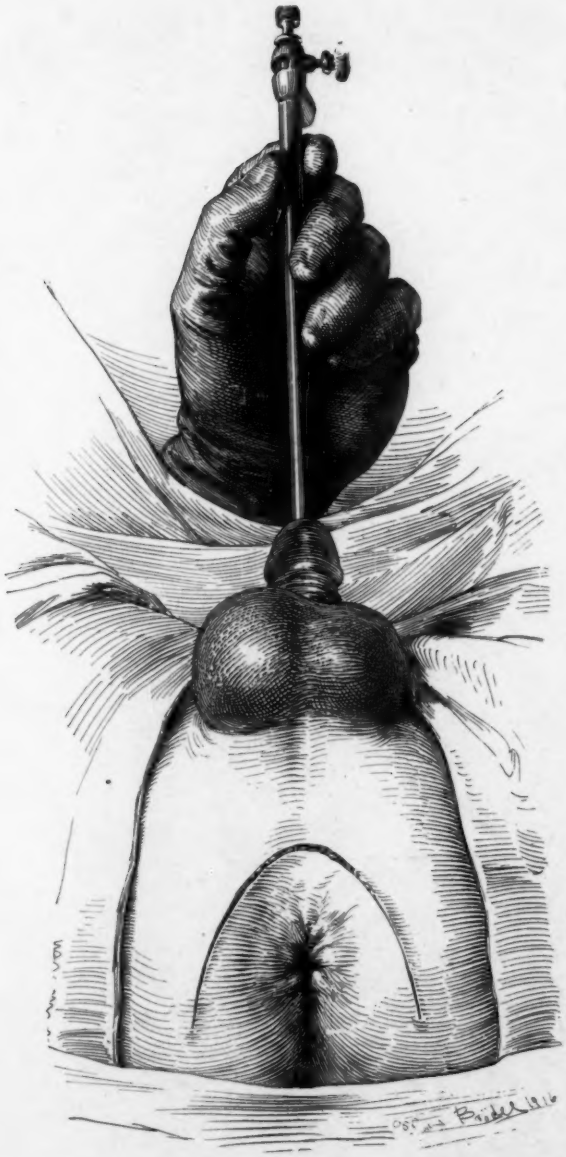

Fig. 2.—Cutaneous incision, with tractor in urethra.

TABLE 7.—Results of Fifteen Radical Operations for Tuberculosis of the Seminal Tract

Case Number	B. U. I. Number	Age	Lung Tuberculosis Before Operation	Tuberculosis of Kidney	Perineal Wound Closed	Interval Between Operation and Last Report	Postoperative Tuberculosis of Other Organs	General Health at Present	Final Operative Result
1	3515	28	None.....	Tubercle bacilli from right kidney before operation	5½ weeks.....	7 years.....	None.....	Excellent; slight pyuria; cause undetermined; coitus normal	Excellent local result; no sinus or fistula; micturition normal
2	4150	42	Old lung tuberculosis	None.....	Small fistula	Lived one year after radical operation	Lung tuberculosis before operation; abscess of chest wall, shoulder, epididymis, mediastinum later	Developed tuberculosis of mediastinum, chest wall, right shoulder; died 1 year later	Persistent urinary fistula; opposite epididymis involvement 1 year later
3	3632	22	Old lung tuberculosis	None.....	3 weeks.....	2 years, 7-8-16	Returned with tuberculosis of other epididymis, 2 yrs. later; epididymectomy, 6/30/16	General health excellent, 7/8/16; letters not answered and not returned	Involvement of other epididymis; cured by operation; condition otherwise excellent; no perineal fistula; urination normal
4	4322	..	None.....	None.....	5 weeks.....	Not heard from; letters not returned	None; patient refuses to answer letters	Condition good on discharge, 6 weeks after operation; wound not healed, fistula present before operation	No report since leaving hospital, condition good then
5	4330	30	None.....	None	Small fistula still open	6 years.....	None.....	Good; micturition normal; interval 3 hours	Excellent local result; second epididymis not involved; small urinary fistula persists
6	4080	34	None.....	None.....	Sinus still open; not urinary	5 years.....	None.....	Excellent; sexual powers normal; urination normal	Excellent result; small perineal sinus; no urinary fistula
7	7983	27	Old lung tuberculosis; suspicious fibroid tuberculosis	Left nephrectomy, 4 mos. previously	5 weeks.....	14 months.....	None since operation; previous kidney and bladder; tuberculosis, nephrectomy	Condition much improved; urination frequent but much improved; coitus normal	Excellent result; perineal sinus, not urinary

8	8486	51	None.....	None.....	4 weeks.....	1 year.....	None.....	Excellent; sexual powers satisfactory	Excellent local result; no sinus or fistula
9	8525	19	History of empyema; probable lung tuberculosis	None.....	3½ weeks.....	1 year.....	None (no flare up of old empyema or lung tuberculosis)	Good; no urinary complaint; sexual powers satisfactory	Excellent local result; no fistula; no sinus
10	8561	43	Suspicious fibroid tuberculosis	Pus and tubercle bacilli in urine, right kidney	Sinus still open; not urinary	1 year.....	None (no flare up of old suspected lung tuberculosis)	Excellent; much improved; micturition better; impotent before operation	Local result excellent; small sinus in scrotum; no fistula
11	8681	23	None.....	None.....	3 weeks.....	1 year.....	None.....	Excellent; sexual powers normal; micturition normal	Excellent local result; two small sinuses; no urinary fistula
12	8712	48	Chronic tuberculosis of lungs; state sanatorium	None.....	2 months.....	11 months.....	Old tuberculosis of lungs; condition still quiescent	Good; much improved; still has cystitis and frequency	No local recurrence; two discharging sinuses; no urinary fistula
13	8707	25	None.....	Present before; left nephrectomy, 3 mos. later	2 weeks.....	10 months.....	Tuberculosis of left kidney, present before, removed 3 months later	Improved but still suffers with pyelitis	Good local result; no urinary fistula; small sinus; cystitis
14	8729	30	Suspicious fibroid tuberculosis; arthritis (tuberculosis?) of spine, etc.	None.....	2 weeks.....	11 months.....	General arthritis before; involvement of rib, mastoid and foot since operation	Improved; now able to walk	Excellent local result; no fistula; urination good
15	5430	30	None.....	Right nephrectomy, 3 years previously	3 weeks.....	3 months.....	None.....	Good.....	Excellent local result; no fistula; urination normal

Tabulation: Number of cases, 15; lung tuberculosis present or suspected before operation, 7; kidney tuberculosis before operation, 5 (nephrectomy, 3); operative result excellent in all cases; operative mortality, 0; one death, lung tuberculosis, one year later; not heard from, 1; perineal urinary fistula, 1; persistent discharging sinus, 7; sexual powers normal, 5; impaired by operation, 0; not noted in reply, 10; operative failures, 0.

TABLE 8.—Abstract of Pathologic Report of Seminal Vesicles, Prostate, Etc.

Case Number	B. U. I. Pathologic No.	Seminal Vesicles		Prostate		Vasa Deferentia		Ampullae	
		Right	Left	Right Lobe	Left Lobe	Right	Left	Right	Left
1	1780	Not removed.....	Many small and conglomerate tubercles	No evidence of tuberculosis	No evidence of tuberculosis	Not removed.....	Caliber diminished at upper end; many caseous tubercles at lower end	Not removed	Tuberculosis
2	1742	Not removed.....	Many small tuberculous cavities	Not removed.....	Extensive caseous tuberculosis	Not removed.....	Diffuse tuberculous process, attachment to globus minor	Not removed	Tuberculosis
3	1841	Indurated, nodular, caseous tubercles	Not removed.....	Fibrosis and a few small tubercles	No evidence of tuberculosis	Large nodule of caseous tuberculosis near ampullae	Not removed.....	Tuberculosis..	Not removed
4	2059	Caseous tuberculosis; much scar tissue	Scar tissue throughout; no evidence of tuberculosis	No definite evidence of tuberculosis; scar tissue	No evidence of tuberculosis	Many caseous tubercles	Fibrous throughout; no evidence of tuberculosis	Tuberculosis..	Much scarred; no evidence of tuberculosis
5	2064	Much enlarged; dense scar tissue; many caseous tubercles	Enlarged; small and large tuberculous abscesses	Somewhat fibroid; tuberculosis?	Much fibrosis; many caseous tubercles	Irregularities externally; caseous tubercles present	Nodular; tuberculosis present	Tuberculosis?	Tuberculosis
6	2363	Not removed.....	Small tubercles; much fibrosis	Not removed.....	Caseous tubercles	Not removed.....	Tuberculosis; mostly at lower end	Not removed	Tuberculosis
7	3344	Fibrous; small tubercles	Many caseous areas of tuberculosis	Not removed.....	Not removed.....	Uniform; no evidence of tuberculosis	Fusiform thickenings; caseous areas of tuberculosis	Tuberculosis..	Tuberculosis
8	3365	Hard; nodular; irregular; tuberculosis	Hard; nodular; irregular; tuberculosis	Fibrosis; tuberculosis	Fibrosis; tuberculosis	Uniform throughout; densely inflammatory; tuberculosis	Uniform throughout; densely inflammatory; tuberculosis	Tuberculosis..	Tuberculosis

9	3390	Somewhat enlarged; many tiny tubercles	Somewhat enlarged; many tiny tubercles	Tuberculosis.....	Tuberculosis.....	Not removed.....	Small, uniform in caliber; no evidence of tuberculosis	Tuberculosis..	Tuberculosis
10	3430	Enlarged; fibrous; irregular; many tubercles	Enlarged; marked fibrosis; few tubercles	Few small tubercles	Few small tubercles	Few tubercles at each end	Thickening and few tubercles near epididymis	Tuberculosis..	Tuberculosis
11	*3471	Not removed.....	Firm; indurated; few tubercles	Not removed.....	Not removed.....	Not removed.....	Thickened; some nodules near ampullae; tuberculosis?	Not removed	Tuberculosis?
12	3482	Not removed.....	Enlarged; caseous tuberculosis	Not removed.....	Not removed.....	Not removed.....	Three nodules, upper, middle and extreme lower, contain tubercles	Not removed	Tuberculosis
13	3485	Enlarged; firm indurated; caseous tubercles	Enlarged; hard, nodular; caseous tubercles	Portion, tuberculosis	Portion, tuberculosis	Nodules of caseous tuberculosis in lower portion	No evidence of tuberculosis; uniform	Tuberculosis..	Tuberculosis?
14	3492	Tuberculosis.....	Not removed.....	Tuberculosis.....	Tuberculosis.....	Thickened throughout; lower portion tuberculosis	Not removed.....	Tuberculosis..	Not removed
15	3667	Small, fibrous tuberculosis	Much enlarged; caseous tubercles	Firm; fibrous; tubercles; caseation	Firm, indurated; tuberculosis	Lower portion removed; no evidence of tuberculosis	Uniform in caliber; no evidence of tuberculosis	Tuberculosis?.	Tuberculosis
Résumé									
Removed.....		10	13	10	12	9	13	10	13
Involved.....		10	12	6	9	7	8	8	10
Uninvolved..		0	0	2	4	2	4	0	1
Doubtful.....		..	1	3	0	3	1	2	2
Not removed.		5	2	5	3	6	2	5	2

Bilateral vesiculectomy, 8; unilateral vesiculectomy, 7 (right 2, left 5); in 3 of these cases subsequently remaining epididymis was attacked.

TABLE 9.—Abstract of Report of Pathologic Tissues Removed: Epididymides, Testicles and Kidneys

Case Number	Left Epididymis				Right Epididymis				Testicle		Tuberculosis of Kidney
	As a Whole	Globus Minor	Body	Globus Major	As a Whole	Globus Minor	Body	Globus Major	Left	Right	
1	Enlarged; tuberculosis	Conglomerate caseous tubercles	Caseous tubercles and small abscess	Destroyed by conglomerate caseous tubercles	Not removed	Not removed	Not removed	Not removed	Not removed	Not removed	Tubercle bacilli from right kidney before operation (once) but no further symptoms
2	Enormously enlarged; measures 3 inches in length; many tubercles	Greatly thickened; tuberculosis	Tuberculosis	Tuberculosis	Not removed at first, removed later; diffusely fibroid tubercle bacilli throughout	Removed later, tubercle bacilli	Removed later, tubercle bacilli	Removed later, tubercle bacilli	Enlarged; surrounded by hydrocele; tubercles in part adjacent to epididymis	Not removed	None
3	Enlarged; tuberculosis when removed 2 years later	.....	.....	.....	Enormously enlarged; conglomerate caseous tubercles	Caseous tubercles	Caseous tubercles	Caseous tubercles	Not removed	Tuberculous involvement of part adjacent to epididymis	None
4	Tuberculosis	Caseous tubercles; sinus to skin	Apparently normal	Apparently normal	Sinus present; tuberculosis	Large tuberculous abscess involving testicle and skin	Fibrous; tubercles in upper part	Extensively involved in tuberculous process	Not removed	Tuberculous abscess in lower pole; remainder normal	None
5	Removed one year preceding at another hospital	.....	.....	.....	Enlarged; tuberculosis	Large tuberculous abscess; fistula opening externally	Caseous tubercles	Enlarged, hard and indurated; caseous in portions	Not removed	Normal	None
6	Tuberculosis	Caseous tuberculosis	Caseous tuberculosis	Tuberculosis; least involved of any portion	Not removed	Not removed	Not removed	Not removed	Not removed	Not removed	None
7	Tuberculosis	Conglomerate caseous tubercles	Apparently normal	Apparently normal	Many large caseous conglomerate tubercles	Tuberculosis	Tuberculosis	Tuberculosis	Normal	Small portion removed shows caseous tuberculosis	Left nephrectomy, four months previously; tuberculosis

8	Tuberculosis	Fibrous tuberculosis	Fibrous tuberculosis	Tubercles	Tuberculosis, very extensive	Tuberculosis; fibrosis	Extensive caseation; tuberculosis	Large conglomerate tubercles	Small part of upper part of testes excised, tubercle bacilli	Small part of upper part of testes excised, tubercle bacilli	None
9	Tuberculosis	Enlarged; conglomerate tubercles	Enlarged; tuberculosis	Enlarged; tuberculosis	Removed previously with testicle; tuberculosis probable	Removed previously; tuberculosis probable	Removed previously; tuberculosis probable	Removed previously; tuberculosis probable	Not removed	Removed previously elsewhere; tuberculosis probable	None
10	Enlarged; irregular; caseous tuberculosis	Extensive induration; tuberculosis	Tuberculosis	Caseous tuberculosis	Enlarged tuberculosis	Tubercles	Tubercles	Tubercles	Early caseous tubercles present in portion adjacent to epididymis	Not removed	Pus and tuberculosis right kidney; process slight
11	Marked enlarged; tuberculosis; subcutaneous abscesses	Tubercles	Tubercles	Tubercles	Not removed	Not removed	Not removed	Not removed	Not removed	Not removed	None
12	Tuberculosis	Caseous tubercles	Tubercles	Tubercles	Removed later; tuberculosis	Removed later; tuberculosis	Removed later; tuberculosis	Removed later; tuberculosis	Very edematous; few early tubercles	Testicle removed 3 mos. later; tuberculosis	None
13	Enlarged; tuberculosis	Firm, hard and indurated; tubercles	Caseous tubercles	Enlarged; conglomerate caseous tubercles	Tuberculosis	Conglomerate caseous tubercles	Conglomerate caseous tubercles	Conglomerate caseous tubercles	Not removed	Portion removed; fibrous and caseous tuberculosis	Left nephrectomy three mos. later; tuberculosis
14	Not removed	Not removed	Not removed	Not removed	Enlarged; tuberculosis	Few tubercles	Caseous tubercles	Caseous tubercles	Not removed	Not removed	None
15	Greatly enlarged; tuberculosis	Hard and firm; nodular tuberculosis	Enlarged; caseous tubercles	Much enlarged; caseous tubercles	Not removed	.....	.....	.....	.....	.....	Right nephrectomy 3 years previous; tuberculosis
Résumé											
Involved.....	13	13	11	11	11	11	11	11	4 (1 partly excised)	7 (3 partly excised)	5 (3 removed)
Uninvolved..	0	0	2	2	0	0	0	0	0	0	10
Doubtful.....	0	0	0	0	0	0	0	0	0	0	Removed
Not removed.	2	2	2	2	4	4	4	4	12 (1 partly)	11 (3 partly)	

Bilateral excision of epididymis or testicle 10 (3 being subsequent operations in cases of which corresponding ampulla and vesicle had not been excised).

culosis of the seminal tract in the great majority of cases radical operation not only should be the operation of choice but also should be practically imperative. A realization of the bad results obtained by epididymectomy or castration led me in 1913 to devise the radical operation, described herewith.

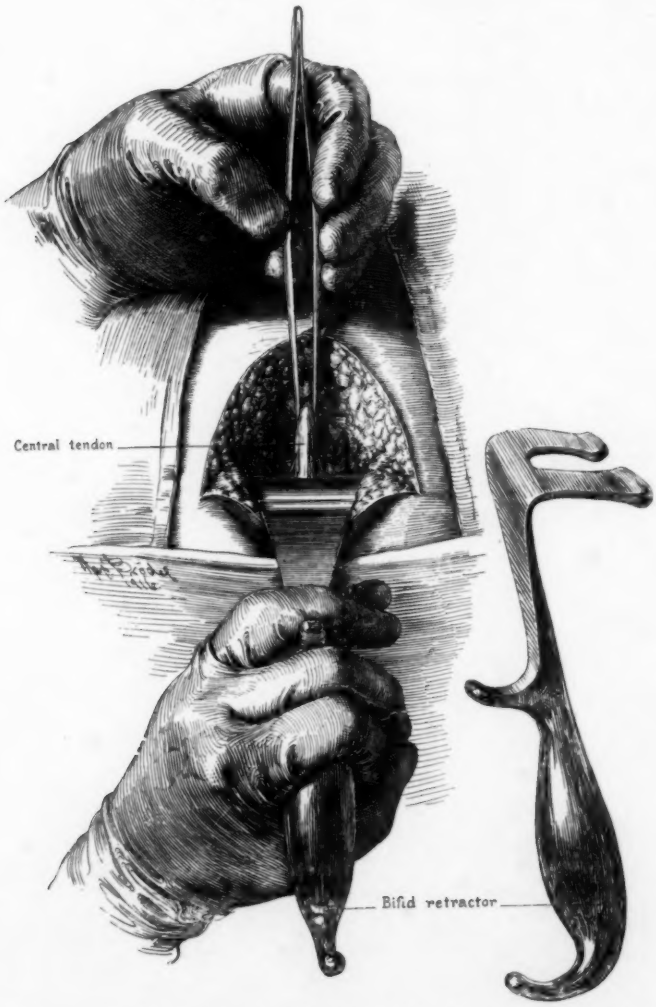

Fig. 3.—Central tendon put on tension by bifid retractor, previous to division.

IV. RADICAL OPERATION FOR EXCISION OF TUBERCULOSIS OF ENTIRE SEMINAL TRACT

The radical operation has been previously described; but it is necessary to refer to it again here (Fig. 1). The ordinary inverted U perineal incision (Fig. 2), which I have always employed for perineal prostatectomy, has been found entirely satisfactory, and after division

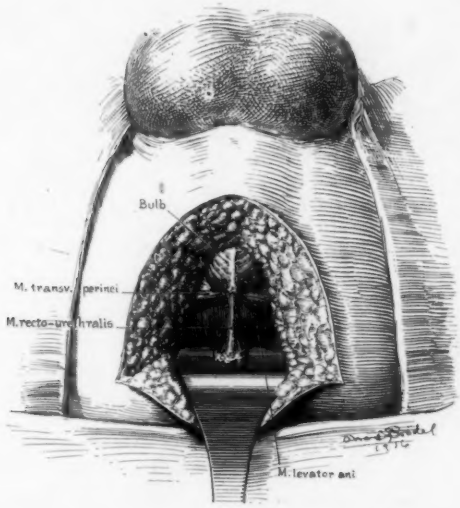

Fig. 4.—Central tendon has been divided, exposing recto-urethralis muscle, which is next divided.

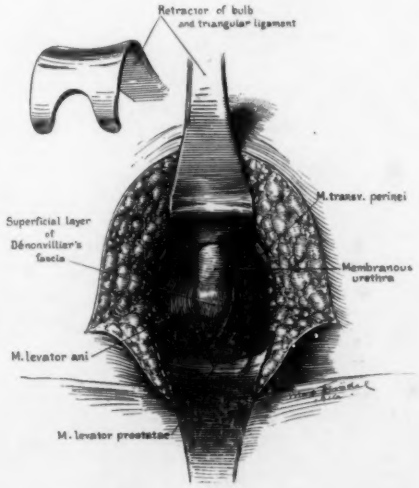

Fig. 5.—Special retractor of bulb and triangular ligament has been inserted, exposing membranous urethra, held up on tractor; the levator ani muscles being next pushed to each side, exposing the posterior or superficial layer of Dénonvillier's fascia.

Fig. 6.—Urethral tractor carried into bladder, where it is opened out as shown in *A* and *B*.

of the central tendon and recto-urethralis muscle (Figs. 3 and 4), the membranous urethra and apex of the prostate are easily exposed without cutting the levator ani muscles (Fig. 5). Up to this point, the tractor has been introduced only sufficiently far to allow its beak to

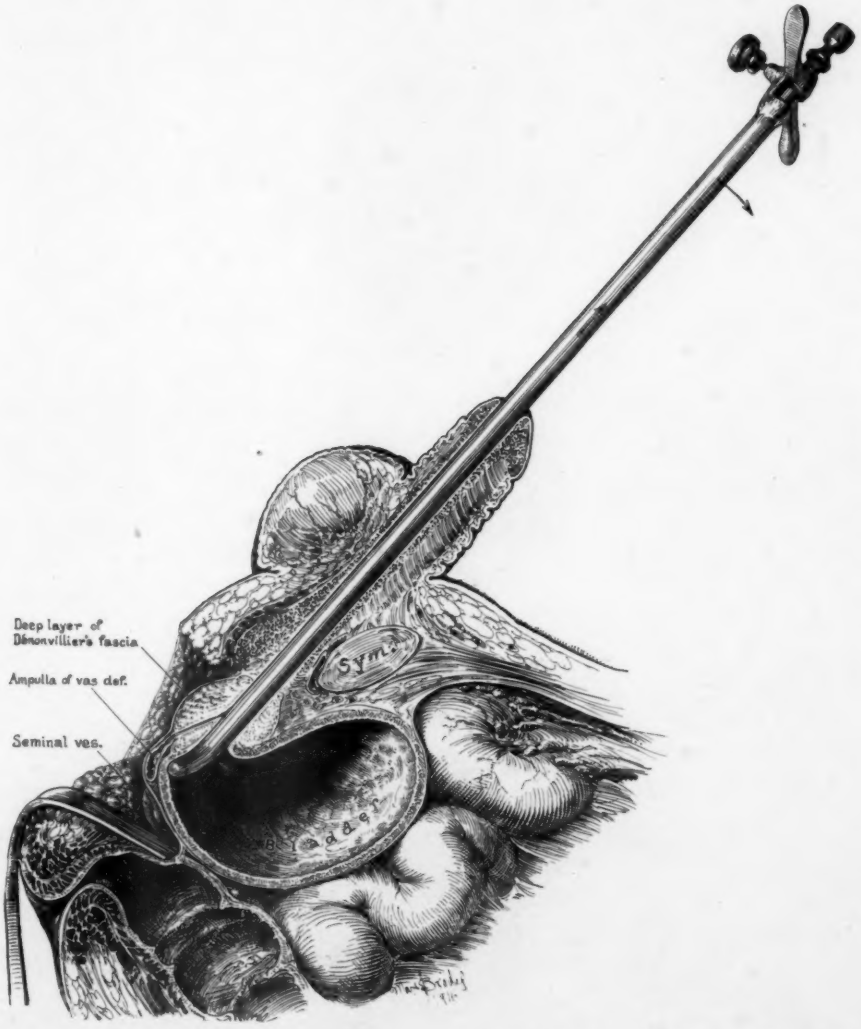

Fig. 7.—Traction and leverage made with tractor, forcing prostate and seminal vesicles into the wound.

lie in the membranous urethra, thus giving an index of this region. It is then carried into the bladder, opened out, traction made and pressure employed (Figs. 6 and 7), thus by leverage forcing the prostate and seminal vesicles up into the wound where little difficulty

is experienced in uncovering the fascia of Dénonvillier, the anterior layer of which forms the covering of, and index to, the seminal vesicles and vasa deferentia as well as the prostate. In this exposure, the levator ani muscle is drawn outward and backward with the rectum,

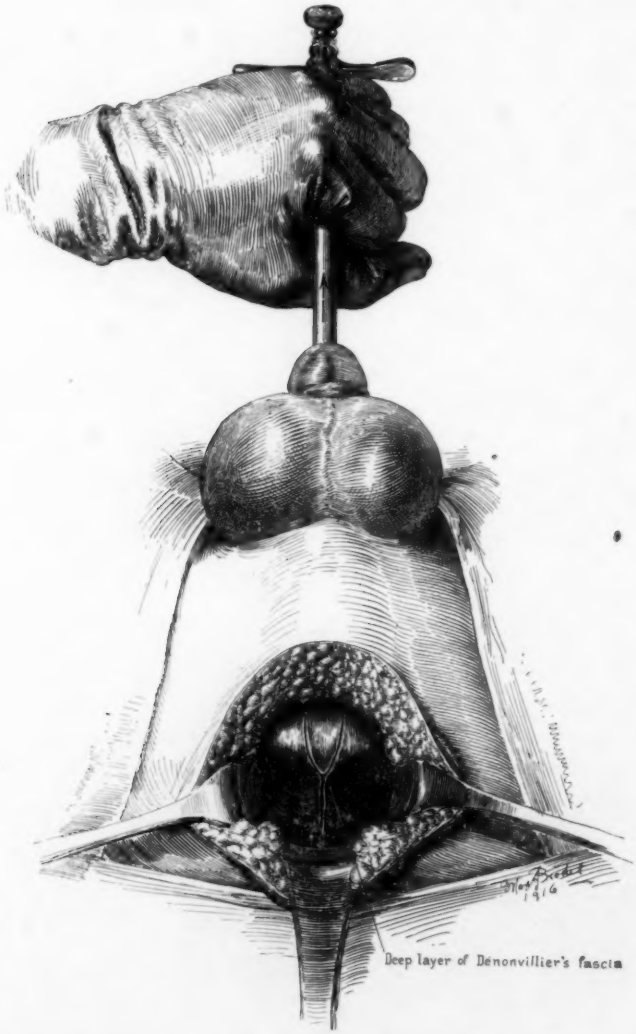

Fig. 8.—Levators and rectum drawn away, exposing fascia of Dénonvillier; Y-shaped incision through fascia.

exposing the superficial or posterior layer of Dénonvillier's fascia, which is divided near the apex of the prostate, thus uncovering the shining anterior or deep layer of Dénonvillier's fascia. The incision which must now be made through the fascia of Dénonvillier in order to

expose the vasa and seminal vesicles may vary somewhat according to the extent and character of the involvement, but as rule a Y-shaped incision (Fig. 8) has been found most satisfactory for nearly all cases in which both seminal vesicles, ampullae and lateral lobes of the prostate are involved. The fascia is then elevated on both sides, thus

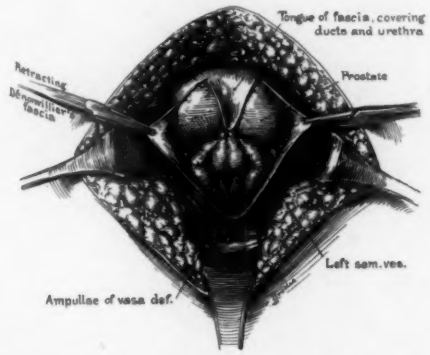

Fig. 9.—Fascia of Dénonvillier elevated by blunt dissector, exposing lateral lobes of prostate, seminal vesicles and vasa deferentia.

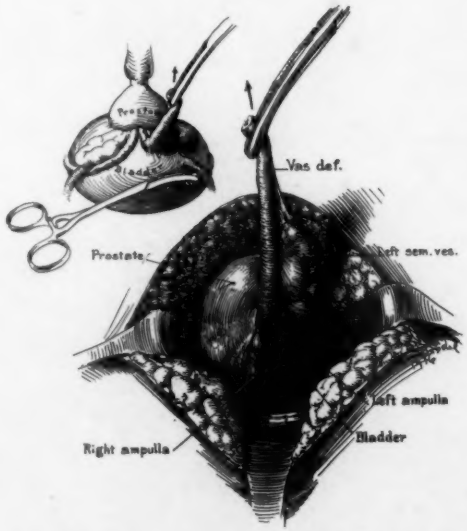

Fig. 10.—Left seminal vesicle freed, vas divided between clamps.

exposing the lateral lobes of the prostate, ampulla and seminal vesicles, and leaving the central portion of the prostate immediately beneath the urethra (in which the ejaculatory ducts lie) intact and covered by fascia, which aids in protecting them. An excellent exposure is thus obtained (Fig. 9), and it is possible to determine exactly how much

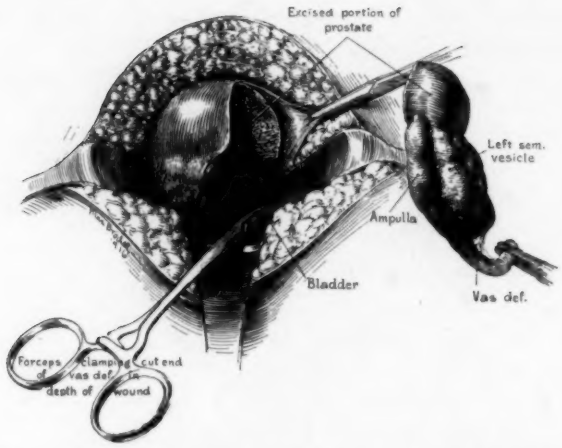

Fig. 11.—Vas, vesicle, and most of left lateral lobe of prostate have been removed in one piece; division of ejaculatory duct near urethra may be noted.

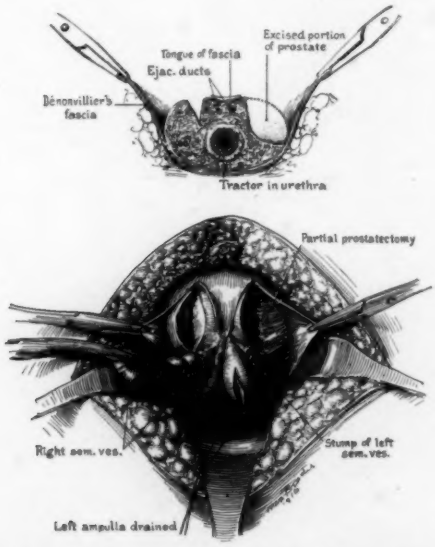

Fig. 12.—Variation: Left vesicle and lobe of prostate excised, and vas drained; right vesicle being freed; line of incisions in prostate may be noted.

should be removed, whether the disease is unilateral or bilateral, and whether one or both lobes of the prostate should be excised. Another advantage of this method is that the main blood supply which lies externally is thus drawn outward with the fascia and hemorrhage is avoided, making it possible to see well and to carry out a delicate and accurate blunt dissection without injury of the bladder, to which the ampullae and vesicles are often very adherent. The vas deferens should be freed well up toward the point where it winds around the ureter and then deeply clamped and divided, the upper clamp being left attached to assist in removal of the upper portion of the vas deferens, in case epididymectomy or castration is contemplated. The seminal vesicle on this side is then freed; firm adhesions being clamped

Fig. 13.—Variation: Showing drainage of vas and vesicle for chronic inflammation; posterior wall of vesicle excised.

Fig. 14.—Drainage and suture.

and ligated after division in order to prevent bleeding; and, working from above downward, the seminal vesicle and ampulla are freed until the juncture with the upper portion of the prostate is reached (Fig. 10). If it seems desirable to remove a portion of the prostate, an incision is made parallel to, and at a distance of 5 mm. from, the urethra (and dividing the ejaculatory duct) but leaving sufficient tissue to avoid a urinary fistula (Fig. 11). After this, the prostate tissue is easily removed by enucleation from within its capsule, and the fascia, ampullae, seminal vesicle, and lateral lobe of the prostate are thus removed in one piece as shown in Figure 22. If the disease is bilateral, the same procedure is carried out on the opposite side (Fig. 21), working from above downward and not separating the ampullae and vesicles from one another, but removing in one piece the vesicles,

ampullae and lateral lobes of the prostate as shown in photographs of specimens removed. The wound is then partly closed, the long clamps being left attached to the upper ends of the vasa deferentia for traction later. In this closure, two iodoformized gauze drains are provided (Fig. 14), and the wound closed as in prostatectomy, leaving room

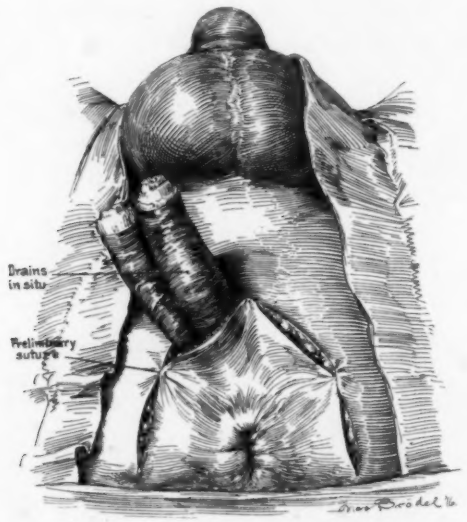

Fig. 15.—Closure and drainage of perineal wound.

Fig. 16.—Incision in groin, with patient in horizontal position on back.

for drainage (Fig. 15). The patient is then placed on his back with the legs separated, and epididymectomy or castration carried out according to the extent of the lesion. This is also so well shown in the illustrations that detailed description seems unnecessary. The incision is usually made along the cord just below the external ring (Fig. 16)

and, after division of the dartos, the testicle is delivered (Fig. 17), the tunica vaginalis opened (Fig. 18), separation of vas and epididymis from veins and testicle carried out, and finally, division at the upper end of the epididymis made with a cautery (Fig. 19). After suturing the

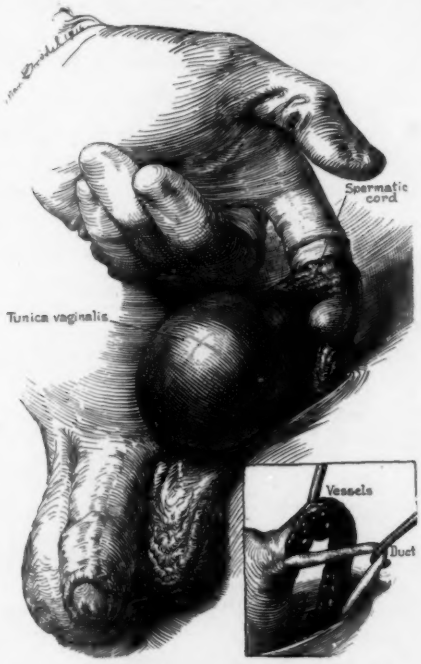

Fig. 17.—Cord and testicle delivered; separation of vas from vessels.

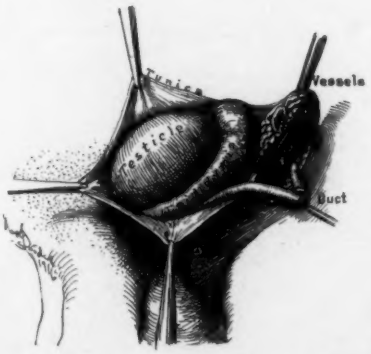

Fig. 18.—Tunica vaginalis opened, exposing tuberculous epididymis.

tunica vaginalis behind the testicle so as to avoid hydrocele formation, and after careful hemostasis, the testicles and veins are dropped back into the scrotum and the vas deferens, which has been exposed up to the external ring, is then freed from adhesions in its canal by a

to-and-fro traction (Fig. 20), produced by an assistant pulling upon the clamp (which I mentioned before as being left upon the lower end of the vas deferens), alternating with traction by the operator upon the vas deferens in the groin. In this way the vas is quickly freed, and, the vas having been liberated from the clamp by the assistant, is easily drawn out in its entirety through the groin, as shown in Figure 21. In this way is accomplished complete and radical removal of the entire seminal tract, with the exception of a few millimeters, the terminal portion of the ejaculatory duct, and we have also a conservative prostatectomy, leaving the urethra and bladder intact. This procedure, which is thorough and radical, is carried out with ease and is entirely under visual control.

Figures 25 and 26 show first of all the impossibility of satisfactory drainage through the natural passages in cases of tuberculosis of the seminal vesicles and the ampullae and epididymides. The tortuous,

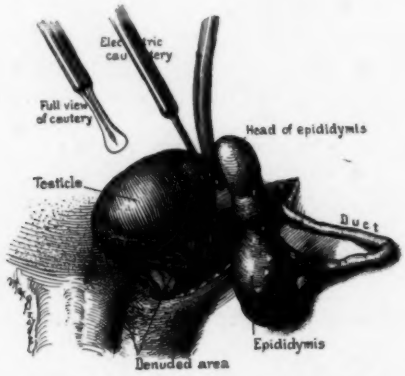

Fig. 19.—Excision of epididymis completed with electrocautery.

sacculated character of these structures is graphically shown in dissections, corrosion specimens, and roentgenograms after the injection of thorium nitrate. The importance of operations upon the vesicles in these conditions is clear.

V. HISTORIES OF FIFTEEN CASES OF EXCISION OF SEMINAL TRACT

A brief account of each of these cases, with operations, pathology and results is presented herewith. Later on an analysis is given.

REPORT OF CASES

CASE 1 (No. 3515, B. U. I.).—*History.*—C. K., aged 28, single, admitted, April 10, 1913, complained of pus in the urine. Twelve years previously he had had fever and night sweats and had lost weight, but there had been no hemoptysis. He had gonorrhea eight years previously, which lasted six weeks, complicated by rheumatism. There was no renal colic, stone or hematuria. Two

months previously, he was examined by a physician who found pus and tubercle bacilli in the urine. Cystoscopy and ureteral catheterization by a physician in New York were reported to have shown tubercle bacilli from the right kidney. He now suffered no pain, felt perfectly well and voided urine normally, and had passed no blood.

Examination.—The right kidney was apparently distinctly enlarged and felt firmer than normal; the left kidney was negative. Both testicles, epididymides, cords and groins were negative. The prostate was normal in size, smooth,

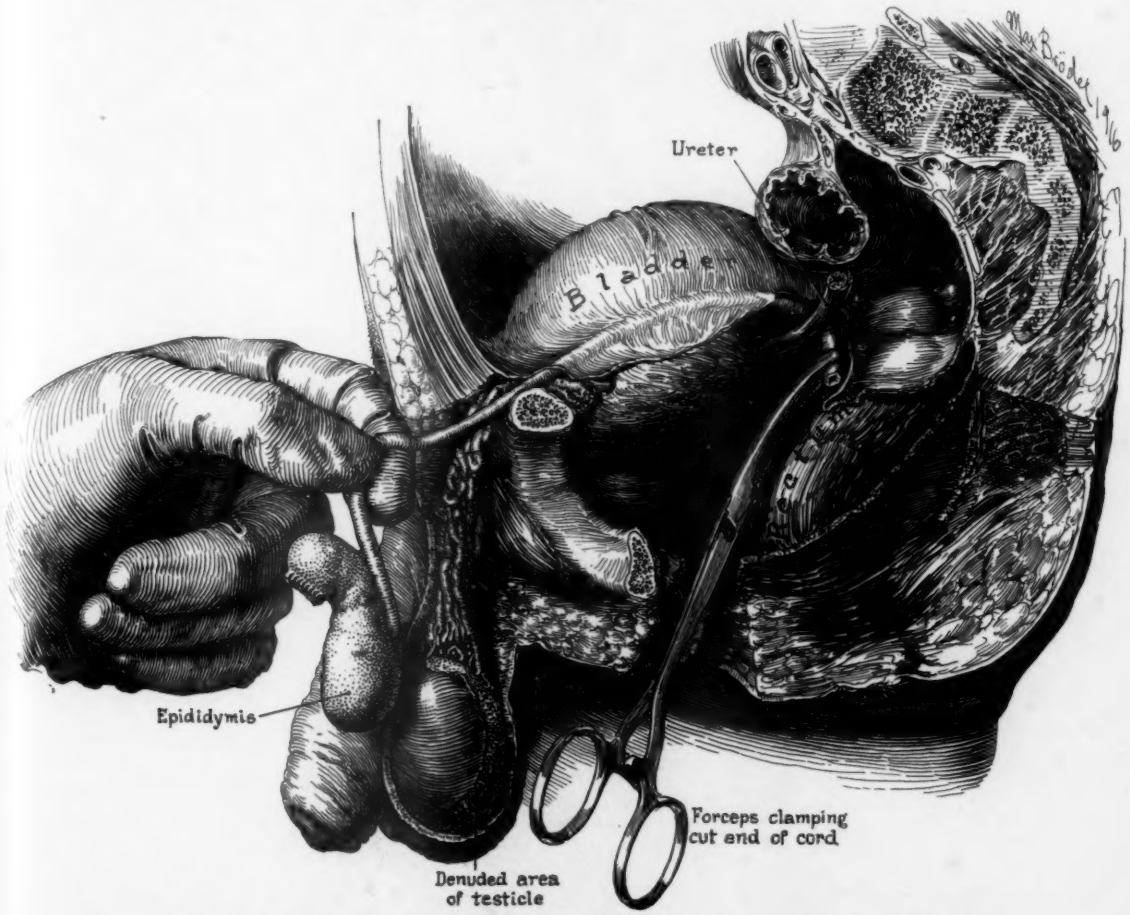

Fig. 20.—Method of traction (alternating between operator in groin and assistant pulling on clamp in perineal wound on vas) by which vas is freed and then drawn out through inguinal canal.

not indurated or tender. Both seminal vesicles were negative. The urine was clear; microscopically, there was only an occasional leukocyte. No tuberculosis was found. Cystoscopy revealed: no residual urine; bladder capacity 380 c.c.; no stricture. The left ureter was normal in appearance. The right ureteral ridge was slightly swollen, and the mucous membrane around the orifice was edematous. On the anterior wall of the bladder, very small red

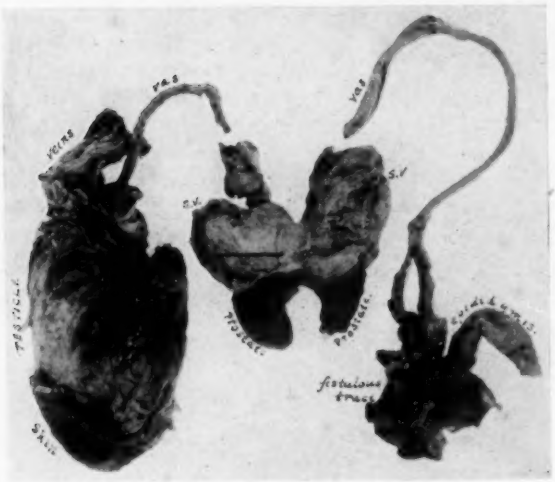

Fig. 21 (Case 4, No. 4322, B. U. I.).—Specimen, showing removal of both vesicles, vasa and lateral lobes of prostate; median portion and urethra preserved; castration on one side, epididymectomy on the other.

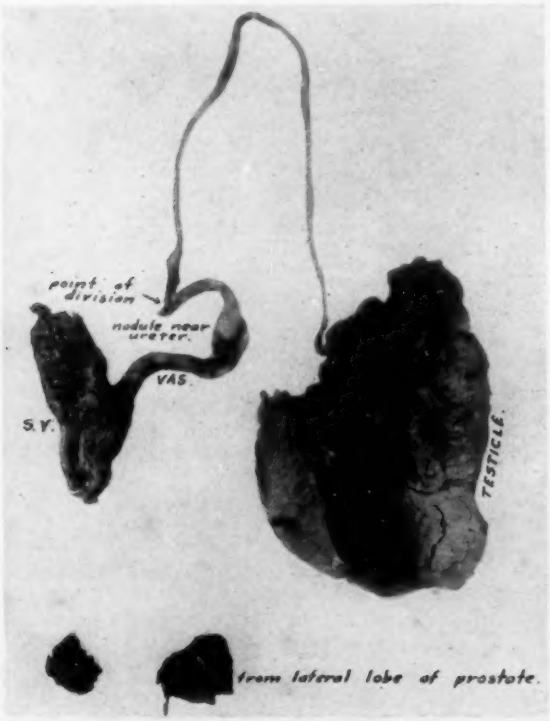

Fig. 22 (Case 3, No. 3632, B. U. I.).—Testicle with surrounding inflammatory tissue, vas, seminal vesicle, and a portion of prostate removed.

areas were seen in the mucous membrane. No ulceration was visible. The rest of the bladder was negative. The prostatic orifice was negative. Ureteral catheterization revealed: right side, urine cloudy; microscopically, epithelial cells, an occasional leukocyte. No bacteria were found. Urine from the left side was clear, and microscopically negative.

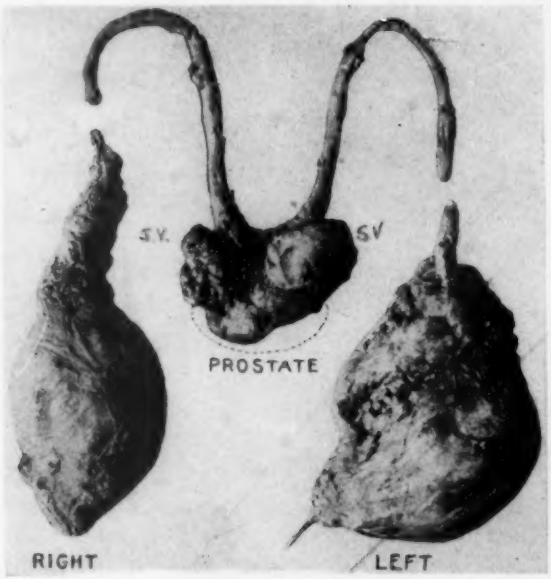

Fig. 23.—First total excision of seminal tract, bilateral, and part of prostate ever performed (1900).[14]

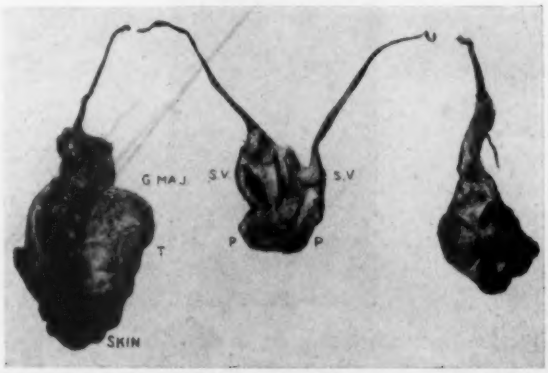

Fig. 24.—Specimen from second case in which removal was accomplished by suprapubic retrocystic extraperitoneal route.

The patient was advised to go to a mountain resort, Saranac Lake. Here pus and acid-fast bacilli were found in the urine; but animals injected with the purulent urine did not die of tuberculosis. March 24, 1914, a letter from this physician said: "Last catheterized specimen of bladder urine contained numerous tubercle bacilli." One month before, and two days after intercourse,

14. Young, H. H.: Ann. Surg. **30**:601, 1901.

there was a slight pain in the upper end of the left epididymis. The next day the swelling had increased very rapidly so that there was a marked enlargement, which seemed to involve the entire testicle and was very tender. Swelling has remained; but the pain has now disappeared. There is no difficulty or frequency of urination.

Urine voided in three glasses was clear, and contained only a few fine shreds in all three glasses. There was no urethral discharge. The right testicle, epididymis and vas were normal. The left side of the scrotum was

Fig. 25.—Injection of vesicles with thorium, showing tortuous cavities and impossibility of adequate drainage.

Fig. 26.—Corrosion specimens showing multiplicity of cavities in vesicles.

enlarged and reddened; there was a small hydrocele but the testicle did not seem enlarged or indurated. The entire epididymis was greatly enlarged, markedly indurated and moderately tender, but not adherent to the skin. The vas deferens was slightly enlarged, smooth and slightly indurated. Rectal examination revealed: prostate, normal in size and consistency; right seminal vesicle, palpable, possibly very slightly indurated and adherent; left seminal vesicle, indurated. The inner side of the vas deferens could be palpated for a distance of about 3 cm. above the prostate. Moderate adhesions were present.

Comment.—We were dealing with a definite tuberculosis of the left epididymis, vas and seminal vesicle. Tuberculosis of the right kidney was probable. It seemed wise to excise the seminal tract.

Operation (Young).—April 6, 1914, under nitrous-oxid, oxygen-ether anesthesia, the left seminal vesicle and ampullae and a portion of both lobes of the prostate were removed through the perineum. The right seminal vesicle, ampullae and prostate were not disturbed. The left epididymis with a portion of the skin around the discharging sinus and the entire vas deferens were removed through an incision in the left groin. The testicle was found not to be involved, and was not disturbed. Both wounds were packed and partially closed.

Pathologic Report.—There was extensive tuberculosis of the epididymis and lower portion of the seminal vesicle; the ampullae of the vas deferens were markedly tuberculous; the rest of the vas deferens was not involved.

Course.—May 14, 1914: The patient was discharged from the hospital. Convalescence was satisfactory. There was no urinary leak through the perineum. Both wounds were granulating nicely; there was no fistula. The left testicle was only slightly indurated. The patient retained urine for three or four hours and voided freely without pain. He had had no pain in the region of either kidney. The general health was excellent. There was no cough, expectoration or pyrexia.

Feb. 6, 1915: The patient had been treated with tuberculin and his general health had greatly improved. His chief complaint was the persistence of two small discharging sinuses. The urine was clear and contained microscopically only a few pus cells and no tubercle bacilli. Roentgenograms of the kidneys were negative. Examination of the chest was negative. The kidneys were not palpable or tender. There was a small sinus in the scrotum. The perineal wound healed solidly. Rectal examination showed a slight cicatrix but no evidence of tuberculosis.

Feb. 25, 1920: The patient returned for observation. He said his general health was excellent; he felt completely cured. Sexual powers were quite normal; he had intercourse every week. He passed urine every three or four hours; micturition was normal. He had no pain in either kidney; no fever, chills or night sweats. The right testicle, epididymis and vas were normal. The left testicle was normal in size, smooth and soft; the epididymis and vas were absent. There was no sinus. Rectal examination demonstrated the prostate to be about normal in size and consistency, slightly indurated at the upper end. The right seminal vesicle was apparently soft and normal. The left seminal vesicle was absent; there was slight induration in that region.

March 5, 1921: A letter said: "It is now seven years since operation. I am apparently completely cured, my only complaint being a slight irritation at neck of bladder, lasting a few seconds after urination. Urine voided normally about every three hours and once at night. I have had no trouble with my kidneys. Sexual powers normal. Urine contains pus. My physician still thinks that I may still have an infection of the right kidney."

Case 2 (No. 4158, B. U. I.).—*First Admission.*—L. J. R. D., aged 42, married, admitted, Feb. 17, 1914, complained of a swollen testicle. He had had gonorrhea at the age of 25 and again at the age of 40; syphilis at the age of 37, treated by internal medicine. Four months previously, during "convalescence from typhoid," the left testicle began to swell. It was only slightly

painful in the beginning and since then there had been no pain except during the last few days. There was no complaint referable to the bladder or kidneys.

Examination.—The patient was of apparently excellent physique. The chest showed no definite areas of dulness; no increased fremitus. However, there were numerous râles, of coarse character, over both bases, especially marked between the fifth and sixth ribs, posteriorly. The penis was normal. The right side of the scrotum was normal; the left side was filled with a large rounded mass, consisting of hydrocele and considerably enlarged, indurated, nodular epididymis. The testicle could not be made out in the hydrocele. The vas deferens was indurated and enlarged. Rectal examination revealed: pros-

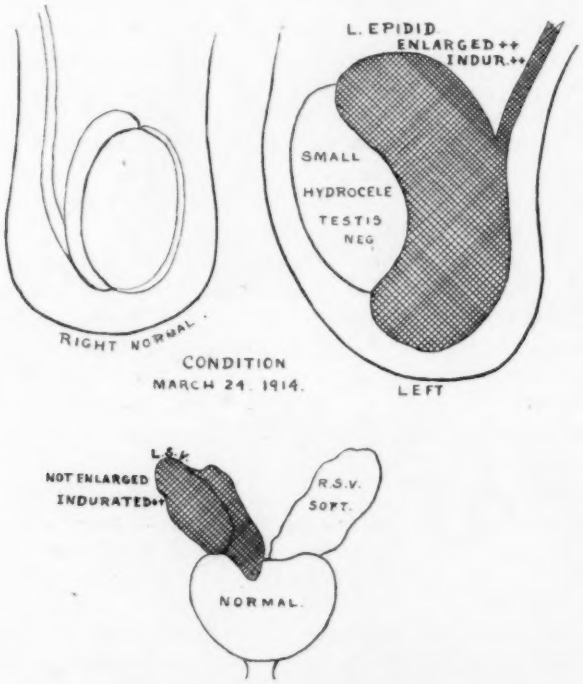

Fig. 27.—Scrotal and prostatic diagram showing regions found involved on examination before operation. This and subsequent diagrams of other cases were made during physical examination of the patient. Normal structures are white; slight induration is indicated by parallel lines; fairly marked induration by crossed lines. Adhesions are also shown.

tate, enlarged on the left side, nodular and very hard; right lobe of the prostate, negative. The left seminal vesicle was also considerably enlarged, indurated and nodular. The right seminal vesicle was only slightly indurated and not enlarged.

The urine contained a few pus cells but no bacteria. One per cent. tuberculin test was positive; Wassermann and luetin tests were negative. The results of the phenolsulphonephthalein test were: appearance time, ten minutes; first hour, 50 per cent.; second hour, 38 per cent. Cystoscopy revealed a normal

bladder. The ureters were catheterized; the urine from both sides was clear, and microscopically negative. This appeared to be a case of tuberculous epididymitis, vasitis and left seminal vesiculitis, and the left lobe of the prostate was affected. It seemed that a radical operation was indicated.

Operation (Young).—Feb. 27, 1914, under ether, a radical operation was performed. The left seminal vesicle (Fig. 28), the ampulla of the vas deferens and the left lobe of the prostate were excised through the perineum. The left testicle, epididymis, cord and the remainder of the vas deferens were removed through a left inguinal incision. Complete closure of the incision and partial closure of the perineal incision with gauze packs followed.

Comment.—The left seminal vesicle and left lobe of the prostate were greatly distended with pus, which escaped during the operation.

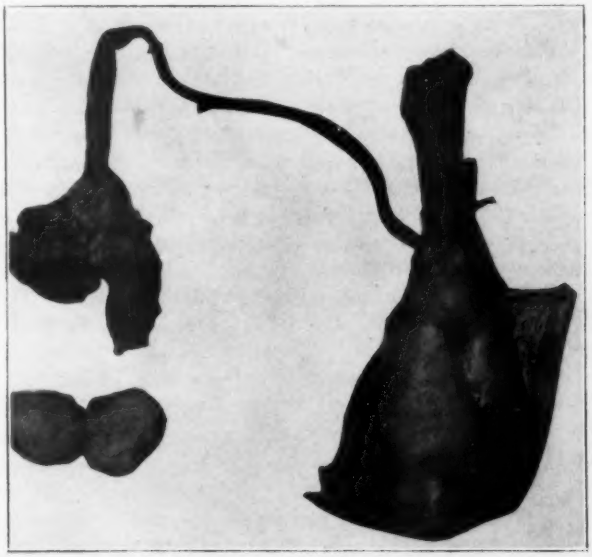

Fig. 28 (Case 2).—Specimen consisting of left vesicle, ampulla and left lobe of prostate removed through the perineum; castration and vasectomy performed through the groin.

Pathologic Report.—The left seminal vesicle and the 5 cm. (2 inches) of ampulla attached were markedly tuberculous. The prostatic tissue removed weighed 5 gm. and was markedly tuberculous, as were also the testicle and epididymis.

Course.—The patient made an excellent recovery from the operation and was discharged, March 22, 1914, with a perineal fistula through which a small amount of urine escaped at times.

Second Admission.—April 13, 1914, he was readmitted complaining of persistent perineal fistula, fever and night sweats. Examination revealed a small fistula in the perineum through which urine escaped. Rectal examination showed slight induration of the right lobe of the prostate and of the right seminal vesicle. The left seminal vesicle and left lobe of the prostate were absent. There was moderate cicatrix; but no fluctuation and no evidence of abscess.

The patient remained in the hospital until July 20. During this time he continued to have fever which ranged between 100 and 102.5 F. at night. The urinary condition seemed excellent. Beck's paste injected into the fistula was ineffectual. The temperature indicated deep-seated tuberculosis, probably of the lungs, but not definitely made out. The urinary tract was negative.

Third Admission.—Jan. 28, 1915, he complained again of perineal fistula. He had had night sweats off and on since his last discharge. For the last two months, he had had pain in the chest and swelling on the left side of the sternum in the region of the second rib.

Examination.—The patient was emaciated; anemic and pale. At the junction of the second costal cartilage with the sternum, there was a rounded fluctuating mass about the size of a small hen's egg, which was not tender. The chest was of the flat type; the infraclavicular fossa was well marked; expansion was poor. The percussion note and vocal fremitus were greater on the right than on the left. Expiration was harsher and more prolonged on the right than on the left. The kidneys were neither palpable nor tender. The penis was normal. On the left side of the scrotum, the testicle was absent, and there was a small discharging sinus. The right testicle was normal in size, shape and consistency. The right epididymis was slightly enlarged, irregular and indurated throughout. The vas deferens was about three or four times the normal size and indurated up to the external ring. In the perineum, there was a scar and a urinary fistula. Rectal examination revealed: right lobe of prostate, slightly irregular, indurated and adherent. In the region of the left lobe, there were adhesions which obscured the outline of the prostate. The tissues were not greatly indurated here nor enlarged. The right seminal vesicle was moderately indurated, enlarged and adherent. On the left side, the testicle was absent and there was only moderate cicatricial induration. The rectal wall was negative.

February 7, the patient was apparently going down hill and had tuberculosis of the remaining seminal vesicle and of the right epididymis. There was apparently also involvement of the lung and probably of the chest wall. It was thought wise to perform epididymectomy under local anesthesia and to inject the seminal vesicle with oil containing iodoform, through the vas deferens into the groin.

Operation (Frontz).—February 8, under local anesthesia (procain 1:400), an incision was made in the groin; the testicle and cord were withdrawn. Epididymectomy was performed, with removal of the vas up to the groin. The wound was closed.

Pathologic Report.—Examination of tissue revealed extensive tuberculosis of the epididymis.

Course.—February 11: Since operation, the patient had suffered with continuous hiccups. The temperature, which before operation rose to 102 or 103 F. every evening, had risen only to 99 F. The fluctuating mass in the chest wall had increased and now measured 8 by 13 cm. and extended from the lower border of the first rib to the upper border of the fourth rib on the left side of the sternum. This was aspirated for diagnosis, and pus withdrawn—no tubercle bacilli or other bacteria were found in it. The abscess was then incised and about 2 ounces (59.2 c.c.) of pus evacuated. Cultures were negative

February 13: A roentgenogram of the chest showed a mediastinitis; generalized involvement of both lungs, especially the upper left, with slight pleural thickening over this region. Both apexes were infiltrated, with some clouding of the right. There was a small consolidated area in the left upper lobe above the third rib. The right side of the diaphragm was "hooked up."

February 20: Hiccups had persisted. The evening temperature ranged between 98 and 101 F. Today, a fluctuating swelling, 3 by 5 cm., appeared beneath the skin of the right shoulder above the acromioclavicular joint. This was incised and about an ounce (30 c.c.) of greenish-yellow pus evacuated.

March 8: The patient had had no hiccups for the last ten days. The wounds in the shoulder and chest wall were still discharging. There was daily evening pyrexia. March 7, temperature was 101.8 F. The perineal fistula was not yet closed. There were no sinuses in the groins or scrotum. The patient was discharged. Owing to the extensive involvement in the chest, the prognosis was bad.

One month after leaving the hospital, the patient died.

Comment.—At the present time, in such a case, with involvement of the lungs, a general anesthetic would not be given; but local anesthesia would be employed as in Case 12.

Case 3 (No. 3632).—*History.*—M. L., aged 23, single, admitted June 1, 1914, complained of pain in the scrotum. The patient denied gonorrhea. Ten months previously, he was treated for sexual weakness by urethroscopic applications of silver nitrate to the verumontanum and received a few massages of the prostate, which were discontinued on account of pain. He received no further treatment until Feb. 1, 1914, when the right "testicle became swollen and tender." There was no urethral discharge and a urologist diagnosed the condition as "lues." The Wassermann reaction was positive and the patient received two injections of arsphenamin. The enlargement did not diminish after treatment with arsphenamin and remained hard and tender. The patient had had no fever, no cough, no frequency or difficulty of urination and no hematuria.

Examination.—The patient was pale and thin. The chest was normal; expansion was free; the lungs, heart and abdomen were negative. Urine voided into three glasses was clear, with numerous shreds in the third glass. Careful examination for tubercle bacilli was negative. Tuberculin eye test was positive. There was no urethral discharge; the penis was normal; the left testicle was normal; the epididymis was slightly tender but not indurated. On the right side, the scrotum was considerably swollen; the testicle was surrounded by hydrocele but was apparently soft and normal. The right epididymis was enlarged throughout and about 1 inch (2.5 cm.) in diameter, hard, tender, with no adhesions to the skin, and no sinus. The vas deferens was apparently normal in size, only slightly indurated and not tender. Rectal examination revealed: left lobe of prostate, enlarged, very hard, particularly at the upper end; right lobe, hard with slight enlargement at the upper end. The lower portion of the right lobe was apparently normal. The right seminal vesicle was a little broader than normal, slightly irregular, slightly indurated and adherent. The left seminal vesicle was soft in its upper portion, slightly indurated and adherent; the lower portion apparently was not enlarged. Neither vas deferens can be made out distinctly.

Operation (Young).—June 5, under nitrous oxid, oxygen and ether, a radical operation was performed, consisting of removal through the perineum of the right seminal vesicle and both lateral lobes of the prostate, all of which were tuberculous. The urinary tract was not opened. Right castration and removal of the remainder of the right vas deferens (Fig. 22) were performed. The wound in the groin was closed completely. The perineum was partially closed and packed with gauze.

Pathologic Report.—The specimen consisted of the right seminal vesicle and ampulla, 11 cm. long, two portions of lateral lobes of prostate, testicle, epididy-

mis and vas, 17 cm. long. The seminal vesicle was indurated, nodular and filled with brownish serum. The ampulla contained a large yellow nodule containing creamy pus. The right lateral lobe of the prostate contained numerous tuberculous areas. The left lateral lobe of the prostate was fibrous; no tuberculosis was seen. The testicle and epididymis both contained numerous areas of caseous tuberculosis.

Course.—The temperature was 102 F. on the fifth day; after that it soon returned to normal. All drains were removed on the fifth day; there was no urinary leakage.

June 26: Convalescence was uneventful. There had been no urinary leakage since operation. The wound had healed. The patient was discharged in good condition.

Jan. 13, 1916: The patient returned much improved. He retained urine five hours and did not have to void at night; there was no urinary symptoms There was no perineal urinary fistula. The right testicle and epididymis were missing; the left testicle, epididymis and vas were negative. The right seminal vesicle and left lobe of the prostate (excised at operation) were moderately indurated and cicatricial; the left seminal vesicle was slightly enlarged and indurated. The urine was negative. Careful search for tubercle bacilli was made but none were found.

June 28: The patient returned complaining of recent swelling of the left epididymis. His general condition was good otherwise. There were no urinary symptoms, no sinuses or fistulas. Examination showed that the left testicle was normal, the globus minor of the epididymis was markedly enlarged, indurated and tender, the swelling was almost entirely limited to the globus minor. There was a slight induration of the globus major; the vas was slightly indurated, nodular and enlarged. The left seminal vesicle was markedly adherent, indurated and tender. The prostate was negative. The right vesicle was absent; there was moderate cicatrix. The urine was clear, with a few shreds.

Operation (Colston).—June 30, a left epididymectomy was performed through an incision in the groin. The globus minor was found to be markedly enlarged, with a small abscess between it and the testicle. The globus major and testicle were apparently negative. Complete epididymectomy was performed, with removal of the vas in the groin. The stump was cauterized with phenol and ligated. The wound was closed without drainage.

July 8: The patient left the hospital in six days. The postoperative course was uneventful. The wound healed by first intention. The general condition was excellent.

March 8, 1921: Numerous questionnaires have been sent to the patient. None was returned, although evidently they have been received. It is impossible to get any information as to the condition. The patient was probably alive, but outrageously unappreciative. Apparently, a good result was obtained.

Comment.—In this case and also in Case 2, both seminal vesicles and ampullae should have been removed. This would almost surely have prevented the subsequent involvement of the remaining epididymis and, possibly, have saved life in Case 2.

Case 4 (No. 4322, B. U. I.).—*History.*—J. E., aged 28, admitted, April 17, 1915, complaining of urethral fistula, gave no history of pulmonary disease. He had had gonorrhea seven years previously and again three years later, and for a third time one year previously. About three weeks after the begin-

ning of the last attack, the patient had pain and swelling in the perineum and urination became difficult, a catheter being required for two weeks. Shortly afterward, the patient developed enlargement of both sides of the scrotum. In December, 1914, the swelling in the perineum recurred and an operation was performed, an abscess being evacuated. Since then, the patient had had a perineal urinary fistula. Two weeks later, the "left testicle became soft and ruptured," leaving a discharging sinus. "The right testicle" remained swollen but not broken down. The patient voided urine with considerable difficulty, but most of the urine came through the meatus, a small amount through the perineal fistula. The urinary stream was weak and small; but he had no increased frequency of urination, and did not void at night. There was no history of renal pain or hematuria. Sexual powers were normal.

Examination.—The patient was a poorly nourished, pale man. The chest expansion was good and equal on both sides. The heart was negative. Neither kidney was palpable or tender. The penis was negative. The left testicle was normal in size; there was no hydrocele. At the lower end of the scrotum on the left side were two sinuses from which pus was escaping. They evidently were connected with the globus minor of the epididymis. The globus minor was enlarged about 1 inch (2.5 cm.) in diameter, and markedly indurated. The body and globus major of the epididymis were apparently not enlarged nor indurated. The vas deferens was slightly indurated, but not nodular nor enlarged. On the right side there was considerable swelling of the scrotum, and no sinus. There was a small hydrocele; the testicle was tender; its size was not accurately made out. The globus minor of the epididymis was greatly enlarged, about 1½ inches (3.8 cm.) in diameter and adherent to the skin, at places fluctuating. The body and globus major were also considerably enlarged, indurated and tender. The vas deferens was indurated, but not enlarged. In the perineum, there was a small fistula through which urine escaped. The prostate was broader than normal, irregular, indurated and adherent. The right seminal vesicle was considerably enlarged, indurated and adherent externally. The left seminal vesicle was also much enlarged, indurated and adherent. Between the two, there was an area of induration. The urine was cloudy; specific gravity was 1.011; it gave an acid reaction and contained leukocytes. The cystoscope entered with ease, there being no stricture. Residual urine was about 130 c.c. The bladder was slightly trabeculated; otherwise it was negative. The ureteral orifice negative; both ureters were catheterized. The urine obtained was clear and microscopically negative. The phenolsulphonephthalein test was good and equal.

Operation (Young).—April 15, 1915, under nitrous oxid, oxygen and ether anesthesia, a radical operation was performed, consisting of removal through the perineum of both seminal vesicles, ampullae and a larger portion of each lateral lobe of the prostate, in one piece, without injury to the urinary tract (Fig. 21). The perineal fistula was excised and the wound was partially closed with drainage. Right castration was performed by traction through the groin. Part of the scrotum was adherent to the epididymis and to most of the vas deferens. A portion broke off and did not come away. Left epididymectomy was performed and a section of the scrotum around the sinus was removed. The entire vas was removed by traction through a scrotal incision. The scrotal wound was partially closed, with drainage.

Pathologic Report.—Both seminal vesicles and the right ampulla were tuberculous. The lateral lobes of the prostate were not definitely tuberculous. There

was much scar tissue. The left globus minor was definitely tuberculous, but the body and globus major were apparently normal and the vas deferens appeared to be normal. On the right side, there was a large abscess which apparently involved the globus minor and partially involved the testicle. The remainder of the testicle was apparently normal. The body and globus major of the right side were tuberculous. Microscopic confirmation was obtained everywhere.

Course.—The drains were removed on the fourth day. A catheter was introduced into the urethra.

April 28, the patient had been having pyrexia, reaching as high as 101 F.; his condition otherwise was good. Most of the urine was voided through the urethra; the perineal fistulas were still open. The scrotal wounds were apparently healed.

May 10, the patient continued to have moderate pyrexia every evening. The leukocyte count was 10,000; the chest was negative; the cause of fever was not explained.

May 28, the patient was discharged. The general condition was good. Small fistulas in the perineum were still open and a small amount of urine escaped at urination. (This fistula was present on admission and before seminal vesiculectomy.)

March 15, 1921, numerous questionnaires and letters had been sent to the patient. They had not been returned. The patient is probably alive, but negligent.

Case 5 (No. 4330).—*History.*—S. K., aged 30, married, admitted, April 24, 1915, complaining of swelling of the right testicle, gave no history of venereal disease, and no pulmonary history. The present illness began three and one-half years before with a "small swelling on the side of the left testicle," which gradually became bigger and finally formed an abscess and discharged pus. He consulted a surgeon who performed a left epididymectomy, and after that, the patient had remained entirely well until the present time. Two and a half months before, the right testicle began to swell and, ten days before, a small suppurating sinus appeared. There was no frequency, difficulty nor pain on urination; no history of pain in either kidney nor hematuria. Sexual powers had been normal until two months previously, since when there had been little desire. The patient's general health was good.

Examiation.—The patient was well-nourished, and weighed 170 pounds (77 kg.). The heart and lungs were negative. The kidneys were not palpable. Examination of the genitalia revealed no urethral discharge; the penis was normal; the right testicle was normal; the epididymis was indurated and enlarged; there was a small discharging sinus. The left epididymis was absent (previous epididymectomy); the testicle was negative. Rectal examination revealed considerable induration and enlargement of both seminal vesicles and a portion of the prostate. The right vas was apparently indurated and enlarged.

Operation (Young).—April 25, 1915, under nitrous oxid, oxygen and ether anesthesia, a radical operation was performed, consisting of removal through the perineum of both seminal vesicles, both ampullae and a large portion of the right lateral lobe of the prostate, without opening the urinary tract. All tissues removed were markedly tuberculous (Fig. 29). Gauze drainage was used, with partial closure. Right castration was performed, with removal of all the remaining vas deferens. Examination seemed to show involvement of the testicle as well as of the epididymis. The scrotal wound was drained with gauze and partially closed.

Pathologic Report.—Both ampullae and the lateral lobe of the prostate were markedly tuberculous. The epididymis was tuberculous; but careful examination of the testicle showed no evidence of tuberculosis. The testicle was obscured by a hydrocele and a very thickened tunica, but the testis was normal.

Course.—Considerable shock followed the operation. This was relieved by infusions. Drains were removed on the fourth day. The perineal wound broke down and was very slow in healing. On discharge, three months after operation, the patient had a persistent fistula through which all urine came when he was on his feet. Various methods, including a retention catheter, were employed without success in closing the fistula. His condition otherwise was excellent.

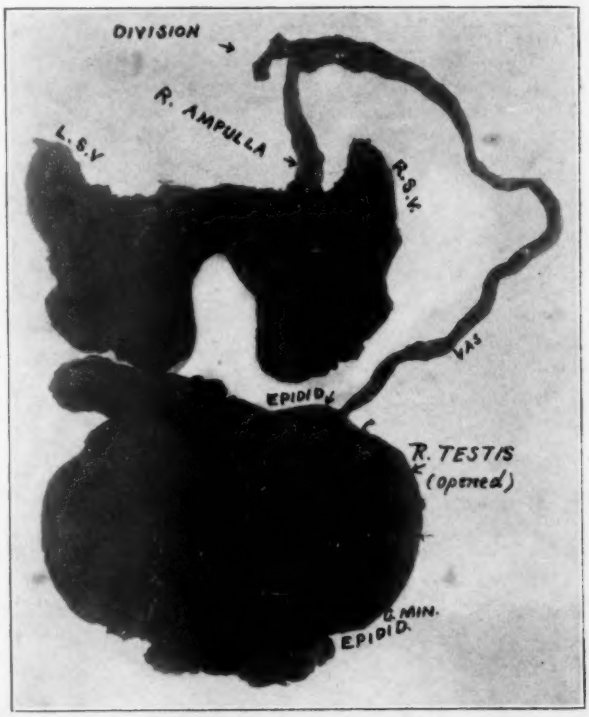

Fig. 29 (Case 5).—Specimen consisting of both vesicles and portion of prostate. Right testicle (shown open), epididymis and entire vas removed.

Sept. 6, 1916, one year after operation, the patient was in excellent health with the exception of a urinary fistula in the perineum. Operation, consisting of the excision of fistulous tract, was unsuccessful. On discharge, he still had perineal leakage.

May 27, 1920, a letter reported: "I void urine entirely without pain about every three hours during the day and twice at night. Urine is clear. I have no symptoms referable to either kidney. No fever nor sweats. General health good. With almost every urination, small amount of urine escapes through perineal fistula. Have no bladder trouble."

Feb. 6, 1921, a letter stated: "Condition same as at last report. General condition excellent. Small urinary fistula persistent. No escape of urine except when voiding and then only a small amount."

CASE 6 (No. 4980, B. U. I.).—*History.*—W. C., aged 34, single, admitted, March 21, 1916, complained of a swollen testicle and a discharging sinus. Pulmonary history was negative. He had had gonorrhea in 1901, but was cured in a few days. There was no epididymitis or stricture. The present illness began three months previously with swelling in the left testicle following traumatism; pain was never very acute. About three weeks previously, the swelling was incised and had since been draining pus. There was no history of any night sweats or loss of weight. Urination and sexual powers were normal.

Examination.—He was a healthy looking man. The lungs were negative with the exception that in the right posterior base, in the scapular line, there

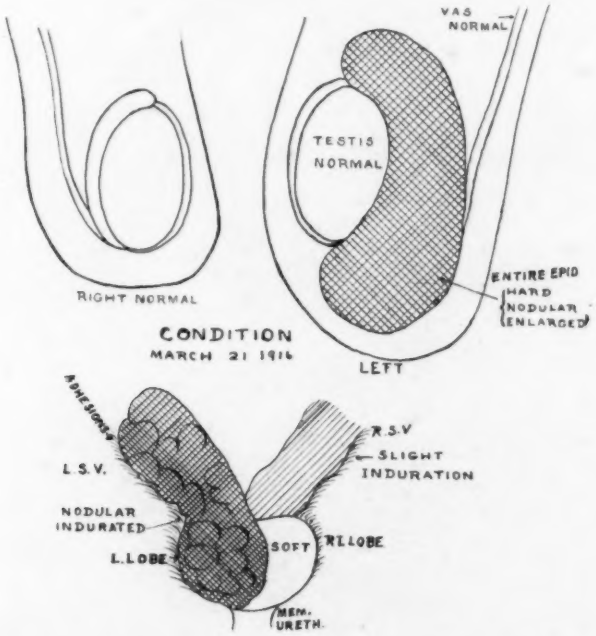

Fig. 30.—Clinical diagram of regions involved before operation.

was a small area in which inspiration had a tubular character. No râles were heard anywhere, even on coughing. The heart and kidneys were negative. The right testicle, epididymis and cord were negative (Fig. 30). The left testicle was surrounded by a soft hydrocele and was apparently negative. The epididymis showed considerable enlargement throughout its extent and was quite irregular, hard but painless; the point of greatest enlargement was in the globus minor, which was about an inch in diameter (2.5 cm.), and from this a small sinus extended through the skin. The left vas was normal. The prostate was not enlarged, but the right lobe was slightly irregular and indurated. The left lobe was a little larger than the right, quite irregular, almost nodular, moderately indurated and adherent. Induration extended up and was continuous, with considerable enlargement and induration of the left

seminal vesicle, which was nodular and adherent. The right seminal vesicle was definitely palpable, but appeared soft and not adherent. The urine was clear and acid; microscopically, a few leukocytes were found but no bacteria, on several examinations.

The impression was that of tuberculosis of the left seminal tract and prostate. Radical operation was indicated.

Operation (Young). — April 3, under nitrous oxid, oxygen-ether, a radical operation was performed consisting of removal through the perineum of the left seminal vesicle and ampullae and a portion of the prostate (Fig. 31). The rectum was very adherent, and a tear was made into it by the finger of the

Fig. 31 (Case 6).—Specimen removed.

operator. Although the tear was extensive, it was decided to continue the seminal vesiculectomy, taking great care not to open the urinary tract. The vesicles were easily exposed. An incision was made beginning at the apex of the prostate on the left side and extending back over the left ampulla, after raising the fascia of Dénonvillier. The left vesicle and ampullae and a portion of the left lobe of the prostate were removed in one piece. The right seminal vesicle, ampullae and right lobe of the prostate were not interfered with. Through an incision in the groin, the entire left epididymis and the remainder of vas deferens were removed. The rectal tear was closed with chromicized catgut; packing was supplied for both perineal and rectal wounds.

Comment.—Examination at operation showed that the left testicle was not involved. The left ampulla was markedly tuberculous and about twice the normal size and very closely attached to the vesicle. The left lobe of the prostate was also markedly tuberculous.

Pathologic Report.—The tissues that were removed showed tuberculosis of the left epididymis, the vas deferens, the left seminal vesicle, the left ampulla and the portion of prostate removed.

Course.—May 20: The patient had been operated on forty-seven days previously. He carried a retention catheter in the urethra for ten days and the bowels were tied up with lead and opium pills. Regardless of this, the rectum broke down and the urinary fistula developed and has persisted.

July 18: The rectal fistula had healed; a small amount of urine escaped through the perineum at each voiding. The patient was able to retain urine for normal periods, had no pains and voided freely.

June 13, 1917, the patient entered the hospital on account of the urinary fistula. He was treated by urethral dilatations. No operation was performed, and he was discharged.

Feb. 1, 1921, a letter stated: "It is now five years since operation. Recto-urethral fistula closed. Perineal sinus persists but there is only a very slight discharge—a few drops of pus a day. No urinary leakage. Urination is normal, can hold urine all night. Sexual powers are normal. No pain after intercourse. Have gained 45 pounds in weight. Urine looks normal; have had no pain in either kidney or bladder. General health perfect."

CASE 7 (No. 7933, B. U. I.).—*History.*—A. R., aged 27, single, admitted, July 8, 1919, complained of bladder trouble. There was no history of pneumonia, pleurisy or tonsillitis. He had had gonorrhea twelve years previously, which lasted for three months. The present illness began two years previously, with pain on urination and passage of blood. Six months later he developed an epididymitis on the left side. The epididymis was opened, pus being evacuated. One month later, the right epididymis became involved. During the past six months, urination had become gradually more frequent and painful. At the time of examination, he voided urine about every hour, night and day, and had a marked urgency and dysuria. He had a persistent discharging sinus from the left epididymis. There was no history of renal colic or passage of calculi.

Examination.—The patient looked well. He had no cough or expectoration. The thorax showed slight retraction in the region of both apexes and an impairment on percussion in that region. The lungs were otherwise negative. The heart was negative. The lower pole of both kidneys was easily felt; apparently there was no enlargement or tenderness. The right side of the scrotum was markedly swollen. There was a tense hydrocele obscuring the testicle (Fig. 32). The right epididymis was markedly enlarged, indurated, irregular, particularly in the globus minor; the vas was normal. The left testicle was normal. The epididymis was markedly enlarged and indurated in the globus minor, the globus major being apparently quite normal. The vas was slightly irregular. There was a small discharging sinus leading to the left epididymis. The prostate was markedly broader than normal; the right lobe was irregular, indurated and adherent. The left lobe was markedly indurated and adherent. The seminal vesicles were entirely obscured by a broad plateau of induration which extended across from one side of the pelvis to the other.

The cystoscope entered easily. The bladder capacity was 50 c.c. The bladder was irritable. The prostatic orifice was slightly irregular but otherwise

negative. The trigon was contracted. The mucous membrane was red, with much mucus adherent and floating about, especially around the left ureteral orifice. The vesical mucous membrane was generally red and edematous; no ulceration was seen.

On the right side, the catheter was easily introduced up to the right kidney. On the left side it was impossible to introduce the catheter. A second attempt at catheterization was made, July 15. The right side was easily catheterized and the urine collected. On the left side, the catheter met an obstruction, 1 cm. above the orifice. No urine was collected from the left side. Analyses of urine collected from the right side revealed: color, amber; clear; no bacteria; an occasional leukocyte and red blood cell.

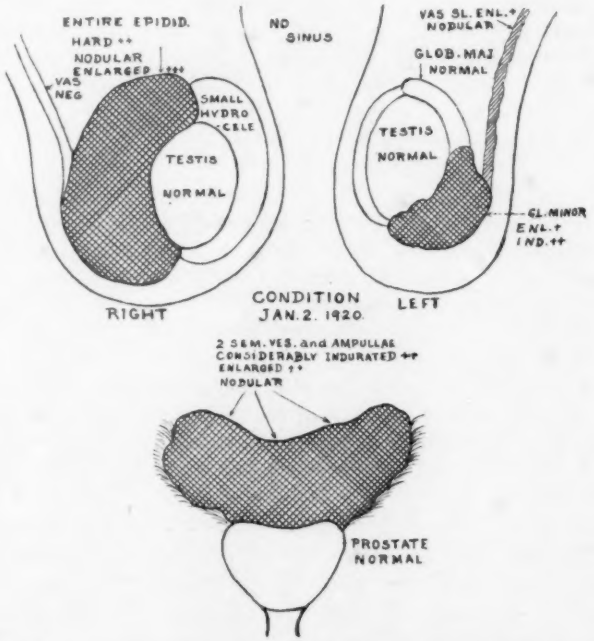

Fig. 32 (Case 7).—Clinical diagram of condition before operation.

August 9, a Garceau catheter was passed into the right ureter. The phenolsulphonephthalein test gave these results: appearance time, four minutes, and 40 per cent. phenolsulphonephthalein excreted in urine collected for one-half hour. During the same time, the transvesical phenolsulphonephthalein output was 5 per cent. Numerous tests for tubercle bacilli were negative; nevertheless, a diagnosis of tuberculosis of the left kidney was made.

Operation (Hain).—August 11, under nitrous-oxid-oxygen ether, a left nephrectomy, extraperitoneal, was performed for tuberculosis. The ureter was brought into the angle of the wound and held there by sutures. The wound was closed with drainage. Convalescence was satisfactory and the patient was discharged, Sept. 6, 1919. His condition was much improved; he retained urine for from two to three hours. The bladder capacity was 95 c.c. There was no dysuria. The scrotal condition was much improved.

Second Admission.—Dec. 30, 1919, the patient stated that during the past two months, frequency and pain on urination had gradually increased so that he voided every fifteen minutes. There was no hematuria or hesitancy, and no pain in the kidney. The patient stated that his sexual powers were good.

Examination.—The patient had lost weight and looked bad. The apexes of both lungs were impaired and a few râles were heard. The right kidney was palpable but not tender. The wound on the left side was well healed. The condition of the genitalia was not markedly changed. The globus minor of the left epididymis was moderately enlarged, very hard and nodular; the vas deferens was slightly enlarged and nodular. The testicle and globus major on the left side were normal. On the right side there was a small hydrocele. The testicle was normal. The epididymis was very much enlarged throughout, very hard and nodular. The vas was negative.

The prostate was slightly indurated and adherent. Both seminal vesicles were much enlarged, very hard, nodular and adherent. Urinalysis revealed cloudy, acid urine, with a specific gravity of 1.022. Microscopically, pus cells and bacilli were found. Culture revealed *B. coli.* The phenolsulphonephthalein test yielded 65 per cent. in two hours.

The impression was one of extensive tuberculosis of the seminal tract. A radical operation was advised.

Operation (Young).—Jan. 7, 1920, under nitrous-oxid-oxygen-ether, both seminal vesicles and ampullae were removed through the perineum. Retrovesical tuberculous involvement was very extensive and the right vas deferens was involved high up and broke away during the dissection. The prostate was not involved. The wound was packed and partially closed. Through an incision in the left groin, the left epididymis and remaining portion of the vas deferens were removed. The testicle was normal and carefully preserved. The entire right epididymis and remainder of vas deferens with the exception of about 2 inches (5 cm.) and a small portion of the right testis were removed through an incision in the right groin. The wound was closed without drainage on both sides.

Pathologic Report (Fig. 33).—There was tuberculosis of the epididymides, vasa deferentia and both seminal vesicles. The portion of the right testicle removed showed marked round-cell infiltration, evidently chronic inflammatory tissue.

Course.—Convalescence was satisfactory at first. One month after operation, the patient was up; the wounds were well healed. There was no urinary fistula; the patient voided about every one and one-half hours.

February 9: The patient complained of discomfort in the bladder. Rectal examination showed a fluctuating area above the prostate, back of the bladder. This was smooth, soft and not tender.

February 18: The rectovesical cold abscess persisted. This was aspirated through the perineum with a large needle and syringe under the direction of a gloved finger introduced into the rectum. Seventy-five cubic centimeters of pus was evacuated. At the same time, a small abscess beneath the skin at the external ring on the left side was opened and drained.

March 9: There was a small perineal discharging sinus at the point the needle was inserted to evacuate the pus. There was no urinary leakage. The urinary symptoms were much improved, the interval now being three hours. Rectal examination showed that the abscess had not recurred. The region of the prostate and seminal vesicles was negative. The right testicle was normal; the scrotal incision was well healed. There was a cicatricial nodule back of the

testicle at the upper and lower ends. On the left side, the testicle was normal; there was a small indurated nodule behind the testis. There was a small discharging sinus at the lower angle of the scrotum. The urine was cloudy and acid, and its specific gravity was 1.012. Microscopically, pus cells and considerable bacilli were found; but no tuberculosis. The patient was advised to live in the open air and take food in abundance.

Feb. 1, 1921, a letter stated that, one year since operation, the disease had not progressed and the testicles had not become involved. The remaining kidney (right) had given him no trouble. There was a small perineal sinus

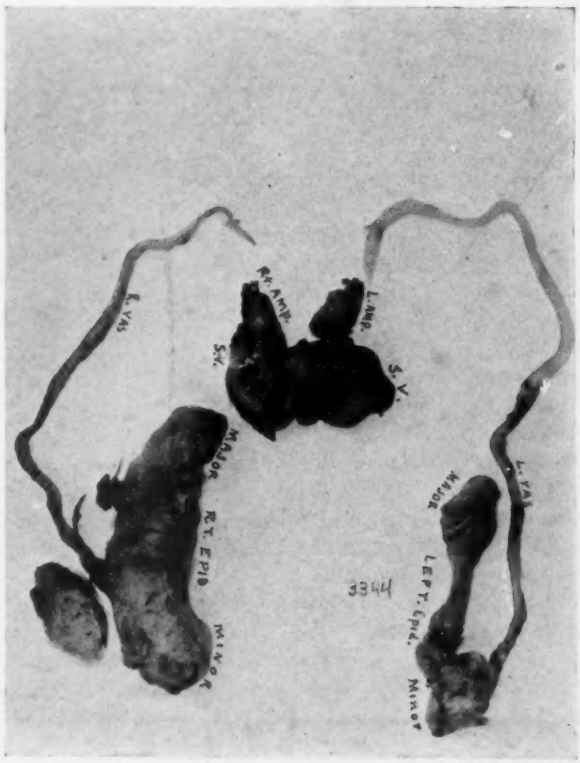

Fig. 33 (Case 7, No. 7933, B. U. I.).—Specimen removed at operation.

which discharged pus but no urine. Erections and sexual powers were good. He continued to have trouble with the bladder. He voided urine about every half hour, night and day. There was no cough, fever or night sweats. His general health was poor, but much improved.

Comment.—The patient continued to suffer with cystitis and contracture of the bladder, which he had when he came here. His life apparently has been saved by nephrectomy and excision of tuberculous tissue of the entire seminal tract on both sides.

Case 8 (No. 8486, B. U. I.).—*History.*—J. K. O., aged 51, married, admitted Jan. 26, 1920, complaining of swelling of the right testicle and fever, gave no history of pulmonary disturbance nor of venereal disease. Present illness

began in 1911 or 1912, when the patient began to have slight difficulty and frequency of urination and finally had complete retention and for six days was catheterized twice a day. Six months later, retention returned and catheterization was again necessary for a time. He had a distinct hesitancy and slight difficulty of urination with a small stream until about October, 1918, when he was operated on for acute appendicitis. He stated that after the operation the frequency, hesitancy and dribbling disappeared until the present trouble, which began seven months previously. There was no history of pain in the region of either kidney, nor passage of calculi nor hematuria. Seven months previously the patient began to have swelling in the right side of the scrotum and since then had developed a swelling on the left side. In August, 1919, epididymectomy was performed on both sides for supposed double epididymitis, and since then he had had a suppurative sinus on the left side. At the time of examination, the patient complained of swelling in the scrotum and fever. He had no urinary symptoms and his general health was good. Sexual powers were normal.

Examination.—The thorax was well shaped; there were equal movements on respiration; the lungs were normal; the heart negative; the kidneys were not palpable nor tender. Roentgen-ray examination of the chest showed a moderate amount of fibrosis and slight dilatation of the aorta. There was no urethral discharge; the penis was negative. On the right side of the scrotum (Fig. 34) there was a small hydrocele. The testicle was normal; the epididymis was considerably enlarged throughout and markedly indurated. The surface was irregular and adherent to the skin at the site of the scar. There was slight enlargement and induration of the vas up to the external ring. On the left side, there were two suppurative sinuses in the skin which led to the globus major of the epididymis. There was a small hydrocele; the testicle was normal; the epididymis was considerably enlarged, irregular and markedly indurated throughout. The vas was apparently normal. Rectal examination revealed a prostate, moderately enlarged, irregular, moderately indurated throughout. The right seminal vesicle was slightly indurated and adherent, but it was not enlarged nor tender. The left seminal vesicle was considerably indurated and moderately enlarged. The induration extended upward and was continuous with the markedly indurated prostate. The urine was slightly cloudy, acid and gave no reaction, and the specific gravity was 1.008. Microscopically, leukocytes and tubercle bacilli were seen. The prostatic secretion contained red blood cells and diplococci.

Operation (Young).—Jan. 30, under nitrous oxid, oxygen and ether, a radical operation was performed, consisting of removal through the perineum of both lobes of the prostate, both seminal vesicles and both ampullae (Fig. 28). Through the groins, both epididymides and the remainder of the vas deferens were removed. The left seminal vesicle was very much enlarged and markedly tuberculous. The right vesicle was much smaller but also tuberculous. The right testicle was indurated, adjacent to the globus major, and a small portion was removed. The left testicle was also involved near the epididymis and partially excised. The membranous urethra was torn during the operation The perineal and scrotal incisions were partially closed and drained with iodoform gauze.

Pathologic Report.—Both seminal vesicles, ampullae, prostatic tissue and epididymides were tuberculous.

Course.—March 2, 1920, the patient had had a very satisfactory convalescence. Both scrotal wounds were healed completely. Both testicles were slightly indurated and enlarged; there was no fistula nor sinus. The patient voided urine with ease. The perineal wound was healed; there was no perineal fistula. Rectal examination revealed a moderate amount of induration in the region of the prostate and vesicles. The patient was walking about; he had no cough and the fever which was present before operation had ceased. The urine was cloudy in all three glasses. Microscopically, white blood cells and bacilli were noted.

May 22, the patient returned for observation. He said that he had greatly improved in health and strength. Urination was normal; there was no fever, no sweats, no pain. The right testicle was normal in size and consistency,

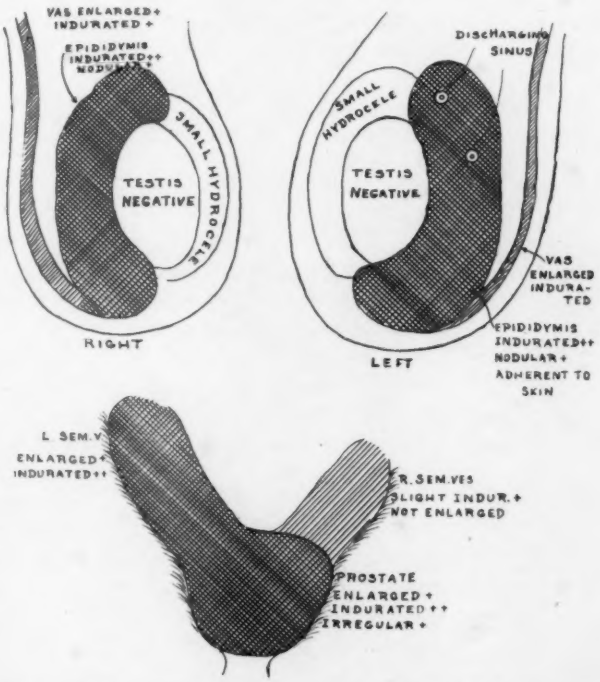

Fig. 34 (Case 8).—Clinical diagram of condition before operation.

except for slight induration of the upper posterior surface. The left testicle was slightly irregular, moderately indurated and adherent to the skin. There was no sinus nor suppuration. Rectal examination revealed only slight induration in the region of the operation on the seminal vesicles and prostate and no evidence of tuberculosis. A small perineal sinus, discharging pus, was still present. There was no urinary leakage. The urine was slightly cloudy. Microscopically, a few cocci but no tubercle bacilli were noted.

September 15: Examination revealed no sinuses or fistulas in the scrotum. Both testicles were negative except for slight induration at the upper ends.

March 10, 1921, the patient came for examination. He said he felt apparently well and entirely cured. All wounds were closed. There was no urinary fistula. His general health was excellent; there was no cough, no fever, and

no sweats. Micturition was normal. He did not have to void during the night. The urine was clear and microscopically negative. No bacteria were present. Sexual powers were normal. He has coitus about once a week. There was less ejaculatory fluid than usual but sensation was normal. Examination revealed slight induration of the posterior part of both testicles. There was no evidence of tuberculosis. There were no sinuses. The perineal wound had healed. There was slight excoriation of the skin from the use of a suspensory. He had gained 25 pounds (11.3 kg.) in weight. Apparently, he was well.

Case 9 (No. 8525).—*History.*—C. R. H., Jr., aged 19, admitted Feb. 17, 1920. complained of a swollen left testicle. In 1917, the patient had empyema which required an operation—resection of a rib and drainage. Two years later, the right testicle became enlarged and castration was performed (July, 1919). There was no history of chronic cough, hemoptysis or night sweats. There was no history of venereal diseases. He had never had frequency, difficult or painful urination, or hematuria. Sexual history was normal.

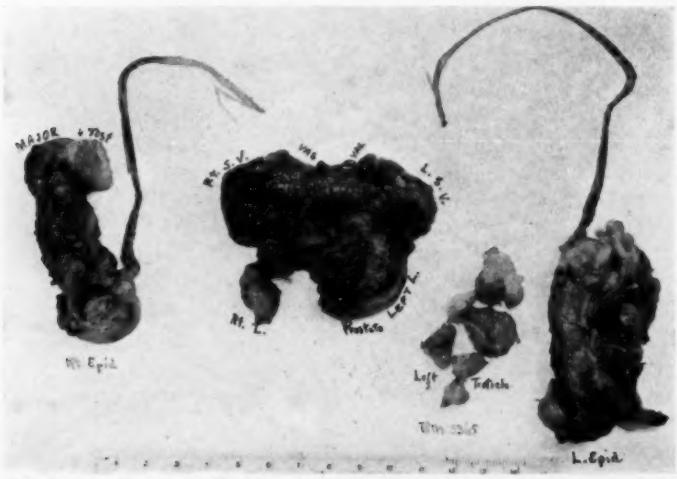

Fig. 35 (Case 8, No. 8,486, B. U. I.).—Specimen removed at operation.

The present illness began four days previously with pain and swelling of the left testicle. There was no history of injury. He still had a discharging sinus in the right scrotum as a result of the castration performed seven months before. The patient was suffering considerable pain in the left testicle, but there was no frequency of urination, no pain, no hematuria, and his general condition was excellent.

Examination.—The patient was well-nourished, height 5 feet and 10 inches (177.8 cm.), weight 155 pounds (70.5 kg.). The lungs were negative on percussion, palpation and auscultation. The heart and abdomen were negative. Neither kidney was palpable. The penis was negative. The right testis was absent (Fig. 36). There was a discharging sinus in the upper part of the scrotum. On the left side, the testis was normal; the globus major and body of the epididymis were negative. The globus minor was enlarged, considerably indurated and tender, and about 2 cm. in diameter. The vas and veins were negative. The urine, voided in three glasses, was cloudy with shreds. Microscopic examination showed pus and tubercle bacilli.

February 18: Cystoscopy revealed no stricture and residual urine. The bladder was negative; the ureteral orifices were normal—both were catheterized. The urine from each kidney was negative. Separate functional tests revealed slight reduction on both sides. Pyelograms were taken. The kidneys and ureters were negative; the outline of the kidneys was normal.

February 25: There had been a rapid increase in size and induration of the left epididymis and a considerable discharge of pus from the sinus in the right groin. Both the vesicles and right lobe of the prostate were considerably indurated and enlarged. Radical excision was advised.

Operation (Young).—March 1, under nitrous oxid, oxygen and ether, a radical operation was performed, consisting of removal through the perineum of both seminal vesicles, both ampullae and both lateral lobes of the prostate (Fig. 37).

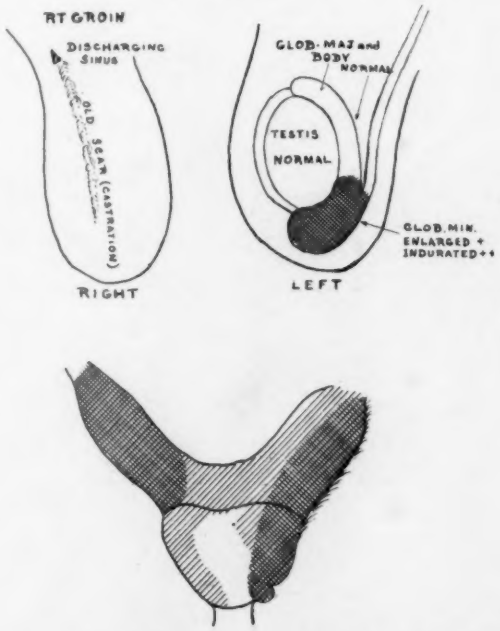

Fig. 36 (Case 9).—Clinical diagram of condition before radical operation but after castration on right side (before admission).

The urinary tract was not opened. All tissues involved in the apparently extensive tuberculous process were removed. The wound was closed with gauze drainage. Through the left groin, the left epididymis and the entire left vas deferens were removed. The wound was closed with drainage. An incision was made in the right groin to investigate the discharging sinus, which had been excised. It was impossible to find the vas deferens, and the portion of the vas deferens intervening between the ampulla and inguinal ring, therefore, remained. The wound in the right groin was packed with gauze. The patient stood the operation well.

Pathologic Report.—There was tuberculosis of both seminal vesicles, both ampullae and the right epididymis. The prostatic tissue removed was apparently tuberculous. The vas deferens was negative.

April 3: It was then three and one-half weeks after operation. The patient had had a satisfactory convalescence. There was no leakage of urine through the perineum. The perineal wound was then closed except for a small sinus. Rectal examination was negative. On the left side of the scrotum was a swollen, inflammatory reaction around the testicle and a small discharging sinus at the site of the wound. There was a discharging sinus in the right groin at the site of the previous castration. The general condition was excellent. The patient was able to retain urine three hours. Urination was normal. The urine was slightly cloudy, with leukocytes and a few bacilli. There was no tuberculosis.

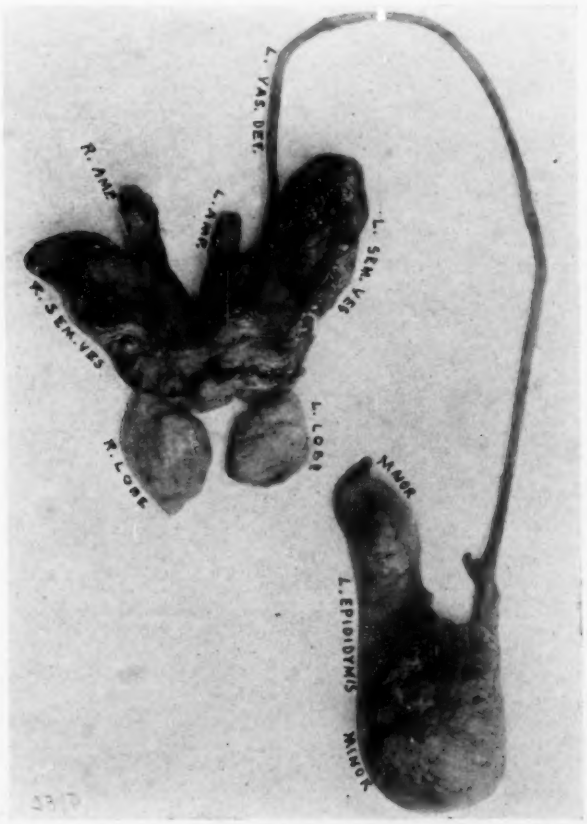

Fig. 37 (Case 9, No. 8526, B. U. I.).—Specimen removed at operation.

April 9: The patient had been treated for four days with bladder irrigations, followed by instillations of 1 per cent. mercurochrome, twice daily. The urine was free from infection. The patient was discharged.

April 16: He returned for observation. There was less swelling of the left testicle. There was a small discharging sinus on the left side of the scrotum. The perineum was closed.

March 12, 1921: A letter stated: "General health good. Excellent result, no urinary fistula. One small sinus in scrotum. Urination normal. No pain. No fever. Erections normal. Urine normal."

CASE 10 (No. 8561, B. U. I.).—*History.*—H. T. Z., aged 43, married, admitted March 8, 1920, complained of frequent and difficult urination. There was no previous urinary history. He denied both gonorrhea and syphilis. The present illness began two years before with increased frequency of urination and pain. Six months later he received an injury on the left side followed by hematuria which soon disappeared. About two months before, he began to have marked pain in the perineum and rectum, and then noticed a swelling in the upper end

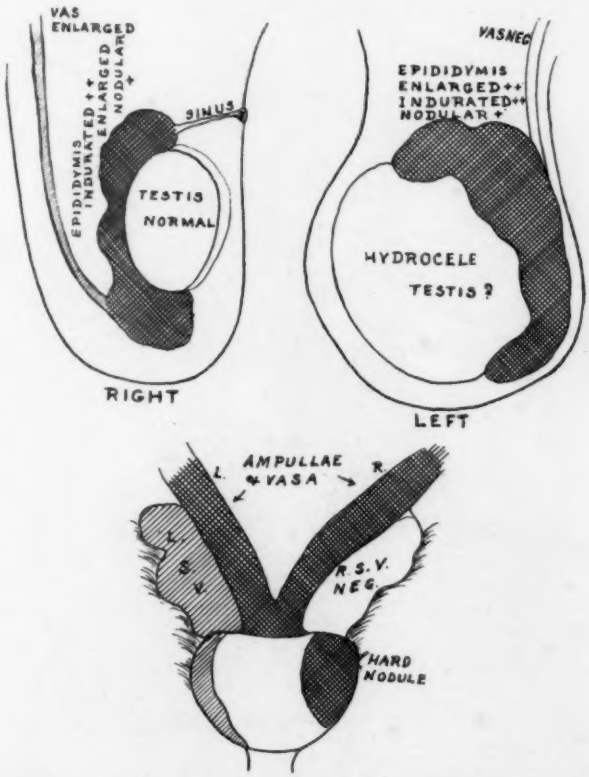

Fig. 38 (Case 10).—Clinical diagram of condition before operation.

of the right epididymis which next involved the lower end. A little later swelling appeared on the left side in the lower end of the left epididymis. After this the upper end of the left epididymis was enlarged. An abscess formed on the right side and was operated on, and has since formed a suppurating sinus. He continued to have frequency of urination and one month ago complete retention. He catheterized himself several times. Since then he has been treated by prostatic massage, irrigations and occasional passage of sounds. At the present time, he voided urine with pain, about every hour. He frequently had attacks of "renal colic" on the left side. Pain so severe that it required morphin radiated toward the groin and bladder and sometimes was felt at

the head of the penis. For the past three months he had suffered with premature and painful ejaculations. He had lost about 4 pounds (1.8 kg.) in weight. He suffered so greatly from pain and frequent urination that he was incapacitated for work.

Examination.—The patient looked healthy. He weighed 150 pounds (68.1 kg.) On percussion and auscultation, the chest was negative except for slightly increased bronchial breathing over the apexes in front and over the lower lobes behind. The heart and abdomen were negative. No tenderness nor enlargement was made out in the region of either kidney. The penis was normal; there was no urethral discharge. The right testicle was normal; the right epididymis was enlarged and nodular throughout its extent. There was a small sup-

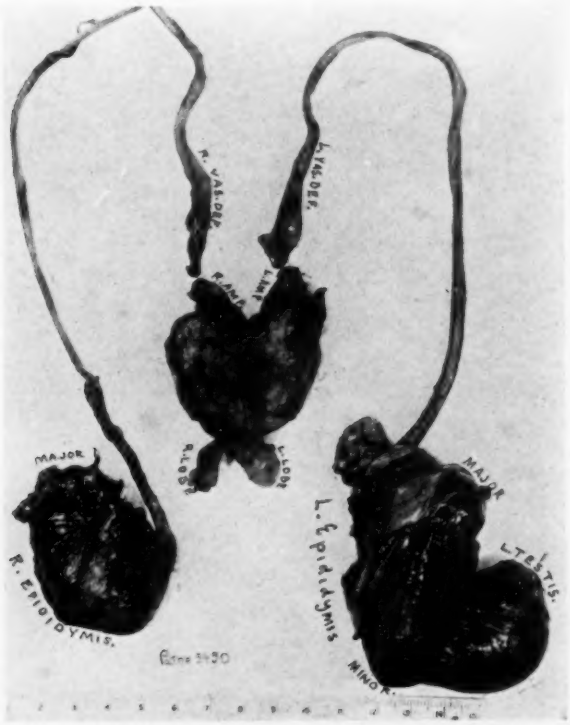

Fig. 39 (Case 10, No. 8561, B. U. I.).—Specimen removed at operation.

purative sinus in the skin, leading to the epididymis. The vas and veins were negative. The left testicle was apparently enlarged considerably but somewhat obscured by an inguinal hernia. The epididymis was enlarged and nodular. The vas and veins were negative. The prostate was negative. Both seminal vesicles were distinctly enlarged, indurated, nodular and adherent. The urine was cloudy and acid. The specific gravity was 1.010. A trace of albumin, a moderate amount of pus, no infection and no bacteria were found. March 10, 1920, cystoscopy revealed no stricture and no residual urine. The bladder capacity was 225 c.c. There was marked diffuse cystitis. The region of the right ureter was edematous and red. External to this was an area

covered with mucopurulent exudate. Around the left ureter and back of it, there was marked reddening and edema, with adherent mucopurulent exudate. Both ureters were catheterized. Urine from the right side was cloudy. A stained specimen showed tubercle bacilli from the right kidney. Urine from the left side was clear. There was no pus, and no bacteria.

March 12, cystoscopy was performed. A study of the prostatic orifice showed a small, rounded median bar. Several areas of definite ulceration were seen along the right and left lateral and posterior walls of the bladder. In other places, small, definite tubercles were seen in the mucosa. Pyelograms and ureterograms showed dilatation of both ureters and of both kidney pelves. Plain kidney and bladder plates were negative. The impression was that of marked tuberculous involvement of the epididymides, seminal vesicles and bladder; slight involvement of the right kidney. It seemed advisable to excise the tuberculous seminal tract.

Operation (Young).—March 21, under gas, oxygen and ether, a radical operation was performed. Through the perineum, both seminal vesicles and ampullae of the vasa and portions of both lateral lobes of the prostate (Fig. 30), all of which were tuberculous, were excised. Through a scrotal incision, the right epididymis was removed, the entire right vas being removed through the wound. The area around the sinus was excised. Castration was performed on the left side. The testicle was markedly involved. The entire left vas was withdrawn through the wound. The wounds were drained and partly closed. The condition was excellent.

Pathologic Report.—Both seminal vesicles, both lobes of prostate, vasa and ampullae were tuberculous. The left testicle and both epididymides were tuberculous.

Course.—March 23, the patient was unable to void. He was catheterized three times a day. A retention catheter was fastened in place that night. March 29, the urine began to drain through the perineum, for the first time. The retention catheter was subsequently removed.

Comment.—It seemed probable that a mistake was made in keeping the retention catheter in for a week. April 9, a small abscess of the left testis was aspirated. April 16, the patient was discharged. There was a sinus in both the perineum and the scrotum. The general condition was much improved, but the patient was weak.

Feb. 4, 1921, a letter stated: "Now almost a year since operation. I have no trouble with my bladder and void four or five times during the day and about four times at night. Urination is not painful and urine appears clear. Have had no trouble with either kidney and the remaining testicle is normal. There is a small sinus in the scrotum on this side. No perineal fistula. Erections and sexual powers are fairly good. Have gained in weight, have no cough and my general health is excellent."

Case 11 (No. 8681, B. U. I.).—*History.*—A. S., aged 23, single, admitted, April 13, 1920, complaining of swelling of the left testicle, gave no history of pulmonary disturbance and no history of venereal or urinary disease. There was no hematuria. Four years before, he had had soreness in the left lumbar region and a second attack six months later. There was no history of calculi. The present illness began about three and one-half months previously, with a small "lump on the left side of testicle," which gradually increased in size and was painful. Three weeks previously, it ruptured and since then a sinus had been present. There was no frequency, difficulty or hesitancy of urination. Sexual powers were normal.

Examination.—The patient was a healthy looking man, weighing 170 pounds (77.2 kg.). The tonsils were enlarged, but there was no general glandular enlargement. The lungs and heart were normal. The kidneys were not palpable nor tender. The penis, right testicle, epididymis and vas were negative (Fig. 40). The left testicle was normal. There was considerable enlargement of the epididymis, with a sinus through the skin. The vas deferens was indurated and enlarged. Rectal examination revealed prostate normal in size and consistency except in the region of the left ejaculatory duct, which was indurated. The left ampulla was indistinctly palpable, being broader than normal and moderately indurated, and could be followed for about 4 cm. above the prostate. The left seminal vesicle was indurated but not enlarged. The right seminal vesicle was soft and apparently normal.

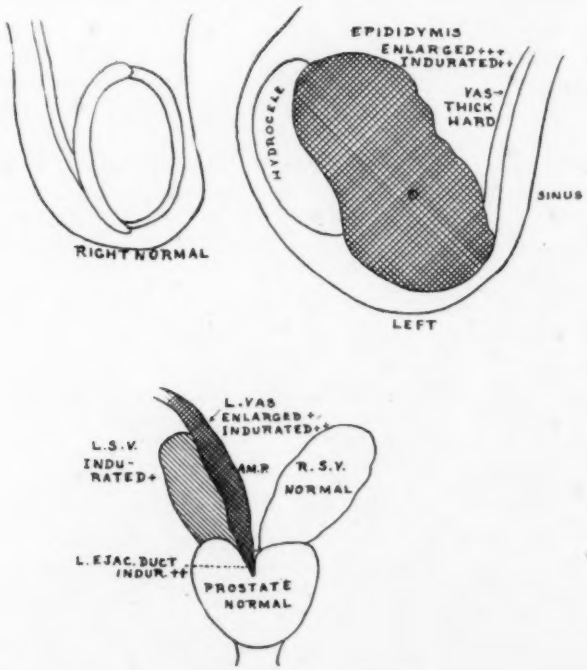

Fig. 40 (Case 11).—Clinical diagram of condition before operation; marked induration of the left vas, ampulla and left ejaculatory duct, distinctly palpable.

Operation (Young).—April 21, under nitrous oxid, oxygen and ether, a radical operation was performed, involving removal through the perineum of the left seminal vesicle and left ampulla (Fig. 41). The prostate and right seminal vesicle and ampulla appeared to be normal. The urinary tract was not disturbed. Through a scrotal incision, the left epididymis was removed, with an area of skin surrounding the discharging fistula. All of the vas was removed by traction. Both wounds were closed with drainage. The patient stood the operation well.

Pathologic Report.—The left seminal vesicle was markedly fibrous and microscopically tuberculous. The entire epididymis was enlarged and tuberculous; the vas deferens contained several tuberculous nodules in various places.

Course.—May 6, 1920: Convalescence had been very satisfactory. It was then fifteen days since operation. The patient was walking. The wound in the scrotum was healed. There had been no urinary fistula and the perineal wound was almost healed. Rectal examination was negative. The general condition was excellent.

Feb. 15, 1921: A letter stated: "Two small discharging sinuses are still present, one in the scrotum, the other in the perineum. Only a few drops of pus escape from each daily. No urinary fistula. Urination normal; no pain in the region of either kidney. No fever, no cough. Have gained in weight. Sexual powers are normal. General health excellent."

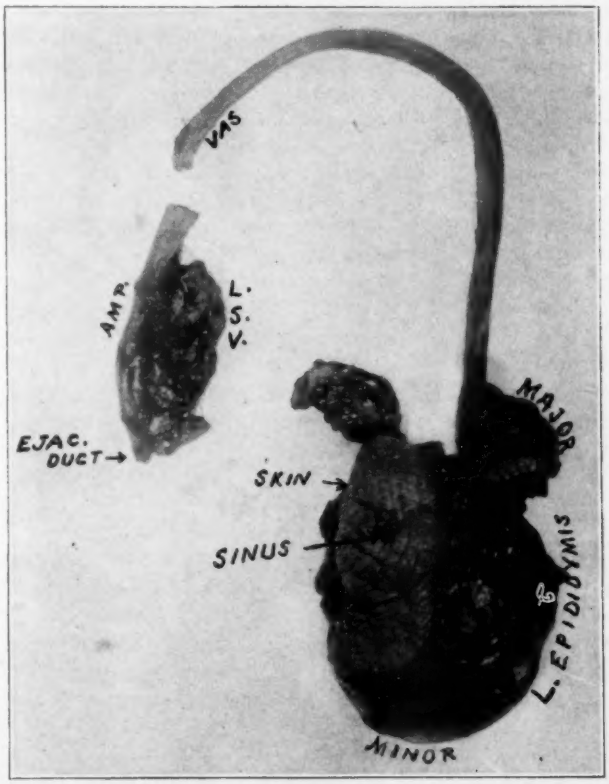

Fig. 41 (Case 11).—Specimen removed: right seminal vesicle not enlarged; tuberculosis largely confined to the ampulla and ejaculatory duct, vas and epididymis.

Case 12 (No. 8712).—*History.*—T. C., aged 48, married, was admitted April 20, 1920, complaining of swollen testicle.

He had had gonorrhea twenty years previously and was apparently cured. Four years before, he developed pulmonary tuberculosis and was treated at the Maryland State Sanatorium. Sexual powers were normal until three years previously. He had had no sexual desire since. The present illness began six weeks before with burning in the penis before urination. Two weeks later, he noticed a swelling of the left testicle, which came on suddenly but had only

been slightly painful and tender. There had been no increased frequency or difficulty of urination; no history of hematuria or pain in the region of either kidney. The patient had not lost weight.

Physical Examination.—He was a fairly healthy looking man, height 5 feet, 11 inches (180.4 cm.), weight 158 pounds (71.8 kg.). The right side of the chest moved more than the left on respiration, and he had an increased vocal fremitus on the right side over the back. The percussion note was equal on both sides. Auscultation disclosed a few râles over the right apex. There was nothing over the apexes in the back. The heart and abdomen were negative. The left side of the scrotum had a hydrocele obscuring the testicle. The left epididymis was considerably enlarged and indurated throughout its entire extent. On the right side, there was a fairly large hernia; the testicle and epididymis appeared normal. The posterior part of the perineum to the left of the median line and in front of the anus presented an irregular, necrotic, superficial ulcer of the skin, probably tuberculous. The prostate was not enlarged or indurated. The left seminal vesicle was indurated, enlarged and adherent. The right seminal vesicle was apparently negative. The urine was slightly cloudy; the reaction acid; the specific gravity 1.024. There was no pus, and no infection, and no tubercle bacilli were found. Phenolsulphonephthalein test results were: appearance time, ten minutes; 50 per cent. first hour; 5 per cent. second hour; total 55 per cent.

The impression was that of tuberculosis of the left epididymis (possibly testicle), vas deferens and left seminal vesicle. Radical excision of the left seminal tract was advised, but owing to tuberculosis of the lungs, general anesthetic could not be given.

Operation (Young).—April 26, under infiltration anesthesia (procain 1:400), with, occasionally, small amounts of gas. Excision of the left seminal vesicle and ampulla of the vas through the perineum, left castration and removal by traction of the remainder of the vas deferens through the scrotum were accomplished (Fig. 42). Both wounds were packed.

Comment.—A tuberculous area of the skin in the perineum was excised before exposing the prostate through the perineum. Local anesthesia was very satisfactory; only occasionally was it necessary to give a very little nitrous oxid gas. The patient complained only moderately of pain. The left seminal vesicle and vas deferens were manifestly tuberculous and were completely excised. The right vesicle, vas and prostate were not attacked. On account of enlargement of the testicle and apparent involvement, castration was performed.

Pathologic Report.—The left seminal vesicle, vas deferens, epididymis and testicle all contained areas of tuberculosis. This was confirmed by the microscope. The vas was 22 cm. long.

May 10: The patient had a very satisfactory convalescence with no urinary leakage. The wound in the left side of the scrotum and the sutured portion of the perineal wound healed by first intention. There was a small perineal sinus discharging a little pus. The patient said urination was distinctly improved since operation; he was able to retain urine longer and had no pain.

July 19: The patient was readmitted to the hospital, complaining of swelling of the right testicle which began ten days after leaving the hospital and had been associated with much pain. The patient had had no dysuria, urgency, hematuria, hesitancy or incontinence, but voided about every hour. The perineal wound had remained healed, but the wound in the left groin had opened a month previously.

Examination.—The right side of the scrotum had a fairly large hernia, a hydrocele of moderate size, obscuring the testicle. There was considerable enlargement and induration of the entire epididymis. Rectal examination showed that the prostate was of about normal size. There was an indurated mass about 2 cm. above the prostate in the region between the two seminal vesicles. There was slight induration along the lateral walls of the pelvis and the region of the left seminal vesicle which had been excised was negative. The right seminal vesicle apparently was not enlarged or abnormal (Fig. 43).

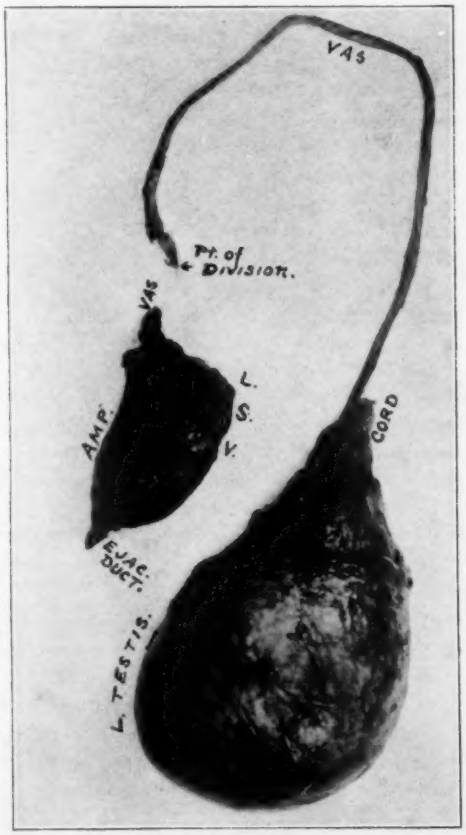

Fig. 42 (Case 12).—Specimen removed under local anesthesia. Left castration, with hydrocele, left vas, ampulla, seminal vesicle and ejaculatory duct.

Second Operation (Young).—July 21, under infiltration anesthesia (procain 1:400), castration, on the right side, was performed. Epididymectomy was not attempted on account of the evident involvement of the testicle. No effort was made to remove the entire vas or the right seminal vesicle, which was apparently negative. The scrotal wound was packed with gauze.

Pathologic Report.—Extensive tuberculosis of the epididymis, with numerous small tubercles throughout the testis, was found.

Course.—Convalescence was satisfactory, the patient being discharged fifteen days after operation with a small sinus in the scrotum on each side; the perineal wound was closed. The general condition was excellent.

September 28, the patient complained of frequency of urination. The cystoscope revealed general cystitis, no ulceration. The ureters were catheterized. Kidney urine was free from infection and both kidneys were of equal function. Bladder urine contained pus cells and numerous cocci. The patient was put on irrigations.

Jan. 21, 1921, the urine showed numerous pus cells and bacilli.

February 11, a letter stated: "Operation one year ago. I am improved but have two discharging sinuses, one on the left side of the scrotum and one in the perineum, which discharge freely. Urination is still frequent, about ten times during day and five times at night, but have no pain in bladder or on urination. Sometimes when on my feet have pain radiating to right kidney from bladder but have had no chills, fever nor sweats. Sexual powers had disappeared three years before operation, no erections. My general health is excellent."

Comment.—Here, as in Cases 2 and 3, both vesicles and ampullae should have been removed at first operation.

CASE 13 (No. 8707).—*History.*—B. N. G., aged 25, married, admitted, April 20, 1920, complained of prostatic trouble. The past history was negative. He denied venereal disease. Sexual powers were normal. About three years previously, he began to have frequency of urination at intervals of about two hours, night and day. About the same time, he had a slight difficulty of urination and pain but he had never had retention or hematuria. Two weeks previously, he began to have swelling in the scrotum but with very little pain. Shortly afterward, a discharging sinus formed (the patient did not complain particularly of either testicle). Urination had continued to become more frequent and difficult. He voided now about every hour, night and day, and there was considerable pain, hesitancy and dribbling. He had not lost weight and there was no history of pain in the chest, or coughing. There was no pain in the region of either kidney.

Physical Examination.—The patient was a well-developed man and appeared to be healthy. The lungs were negative with the exception of a few coarse râles. The heart was negative. The kidneys were not palpable or tender. The penis was normal; there was no urethral discharge. Examination of the scrotum, right side, revealed: testicle, normal in size and consistency; epididymis, considerably enlarged, irregular in the globus minor and body; globus major, apparently normal (Fig. 44). Connected with the lower end of the epididymis was a sinus which discharged pus. The right vas deferens was enlarged, irregular and nodular. On the left side, the testicle was normal; the epididymis was enlarged, irregular and markedly indurated in its entire extent; there were no areas of fluctuation and no sinus. The vas deferens was apparently normal (Fig. 44).

Rectal examination showed the prostate slightly enlarged. The right lobe was prominent, slightly nodular, markedly indurated but not tender. The left lobe was also slightly irregular, moderately indurated, but not enlarged. At the upper end of the prostate on the left side, an indurated cord was felt; it extended upward and outward as far as the finger could reach. On the inner side, another cord was felt, less prominent and less indurated. The outer part of the left vesicle was very slightly indurated and adherent. On the right side, there was an irregular mass of induration, apparently involving the inner

portion of the right vesicle or vas. The outer portion of the right vesicle was apparently not enlarged or indurated (Fig. 44). A few adhesions were present along the outer side of the prostate and vesicles. The rectum was negative. There were no enlarged glands.

The impression was that of tuberculosis of the epididymis, vasa deferentia and both lobes of the prostate. Involvement of the seminal vesicles was questionable. The indication was for radical excision of the seminal tract, including partial prostatectomy.

The urine was slightly cloudy, with acid reaction and a specific gravity of 1.004. A trace of albumin, no sugar or casts, and a slight amount of pus

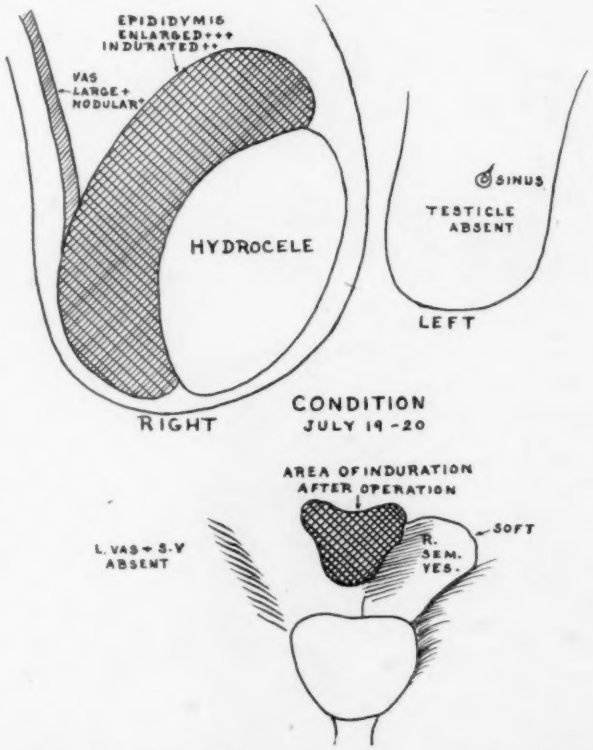

Fig. 43 (Case 12).—Clinical diagram made four months after radical operation, when patient returned with tuberculosis of right epididymis.

were found. Culture revealed colon bacilli in moderate amounts. April 26, the cystoscope entered easily; bladder capacity was 100 c.c. The bladder was irritable; the mucous membrane was diffusely red but not ulcerated. The ureteral orifices appeared normal. In the right ureter, the catheter passed easily up to the kidney. In the left ureter, it was impossible to introduce the catheter more than a short distance; apparently a stricture was present. There was no reaction around the orifice to suggest tuberculosis of the left kidney. Urine from right kidney contained short thick bacilli; no tuberculosis was found. The phenolsulphonephthalein test gave these results: 25 per cent., from

the right kidney in one hour; collection from the bladder for the same period was 3 per cent. Pyelogram of the right side was taken; apparently it was normal.

The impression was pyelitis, right side, slight; probable tuberculosis of the left kidney.

April 29: Additional studies of the bladder urine had demonstrated tubercle bacilli. A second attempt at ureteral catheterization on the right side was successful as before. On the left side, a No. 5 catheter entered for 0.5 cm. Urine flowed through this by drops continuously, clear, pale and microscopically negative. Thorium was introduced into the left ureter and a pyelogram was taken. It showed urethral dilatation beginning at the juxtavesical por-

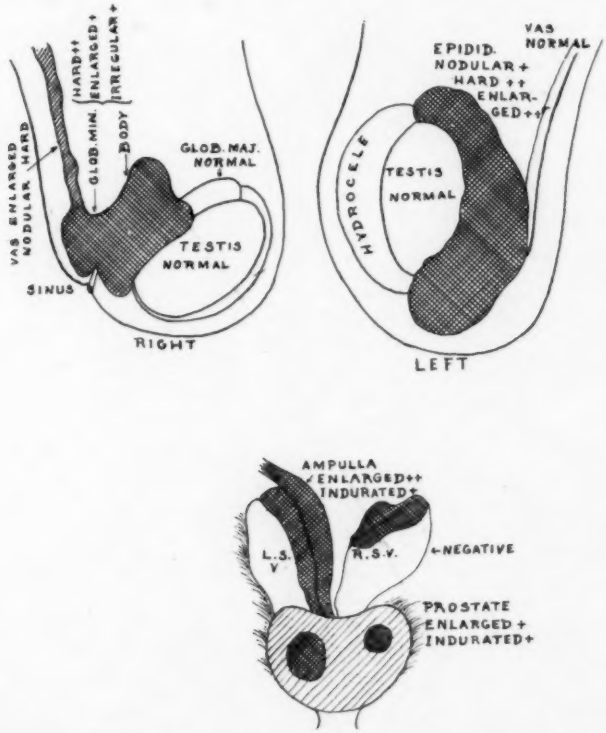

Fig. 44 (Case 13).—Clinical diagram showing interesting isolated areas of marked induration.

tion of the ureter, 1 cm. in diameter in the upper portion. The kidney was apparently normal in size; the pelvis was not well filled. Diagnosis was indefinite. A Garceau catheter was introduced into the right ureter and function was secured. The appearance time was six minutes; the output from the right kidney in a half hour was 28 per cent. At the expiration of the test, the bladder was catheterized and washed out. A transvesical phenolsulphonephthalein (left ureter) gave 18 per cent.

The impression was right pyelitis. There was a stricture of the end of the left ureter, with dilatation above. The left kidney was impaired. Tuberculosis was not proved but suspected.

Operation (Young).—April 30, under nitrous-oxid-oxygen ether, radical excision of seminal tract for tuberculosis was accomplished (Fig. 31): (1) perineal operation consisting of excision of both seminal vesicles, both ampullae and a portion of each lobe of the prostate; the ejaculatory ducts, urethra and bladder were not injured; (2) excision of right epididymis with tissue surrounding the sinus of skin of scrotum and removal of entire vas deferens by traction through scrotum; (3) removal of entire left epididymis and almost all of the left vas deferens.

Comment.—The operation was carried out without difficulty. The deeper portion of the left vas deferens back of the bladder was not removed (the vas broke at that point when traction was made). The perineal and scrotal wounds were closed partially, and small gauze packs were inserted.

Pathologic Report.—The left epididymis was markedly tuberculous. The left vas was negative. Both seminal vesicles were hard and nodular. The right vas was indurated, nodular and tuberculous. The right epididymis showed extensive tuberculosis involving the portion of the testicle which was removed.

Course.—Convalescence was uneventful. Packs were removed on the third and fourth days, and the patient was discharged on the seventeenth day. There was a small perineal sinus discharging pus, and no urinary leakage. The patient had gained in strength; urination had improved greatly; the interval was now four hours. The urine contained pus and bacilli. The general condition was excellent.

June 22: The urine was still cloudy and contained pus and bacilli. It was impossible to catheterize the left ureter. Phenolsulphonephthalein from the right side was 28 per cent., transvesical 5 per cent. in one-half hour. July 7, cystoscopy with successful catheterization of both ureters with No. 7 catheters was accomplished. Urine from the left side was cloudy and contained tubercle bacilli; urine from the right side was slightly cloudy and contained no bacteria. Phenolsulphonephthalein output was equal.

The impression was tuberculosis of the left kidney and ureter. There was a small suppurative sinus on the right side of the scrotum; the testes were normal. The epididymides and vasa deferentia were absent. Rectal examination revealed: prostate, slightly irregular, indurated and adherent, much smaller than before operation; very slight induration in the region of the seminal vesicles, which were absent; no abscess; small perineal sinus.

July 11: The patient was readmitted to the hospital for nephrectomy. The thorax and abdomen were negative. The left kidney was not palpable or tender.

Operation (Frontz).—July 12, under gas and ether, left nephrectomy was performed for tuberculosis. A curved muscle-cutting incision was made in left loin. The ureter was brought up, injected with pure phenol, divided and ligated with chromicized catgut. The kidney which was about the usual size and shape was not opened. The pedicle was ligated with chromicized catgut and the kidney was removed without difficulty. The wound was closed; two gauze packs were inserted. Chromicized catgut was used for muscle and continuous black silk for the skin. Cigaret drains were inserted at the upper angle of the wound. The condition was excellent.

Pathologic Report.—Tuberculosis involving the lower portion of the pelvis and the middle portion of the cortex and medulla was reported. Considerable normal tissue was present.

Course.—Convalescence was uneventful. The patient was discharged, August 11, one month after operation. The wound had healed except for a

small sinus at the upper angle, discharging pus. There was a small perineal sinus, with no urinary or rectal connection. The general condition was much improved.

Jan. 20, 1921: The patient stated that recently urination had become more frequent. A small sinus still persisted at the site of the kidney operation. Urine was cloudy and contained pus cells and bacilli; but no tubercle bacilli were found. The general health was excellent. He had had no fever. Cystoscopy revealed an irritable bladder; residual urine, 75 c.c. The prostatic orifice was normal. The left ureteral orifice was seen as a small depressed

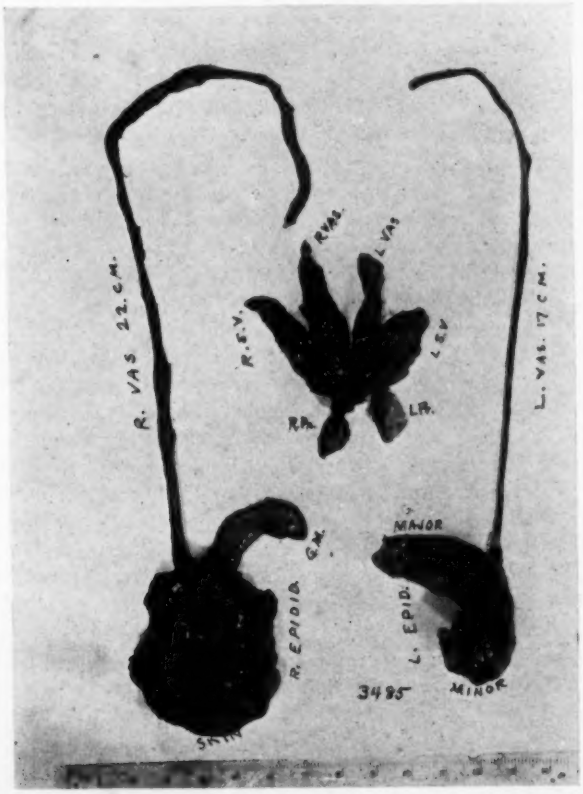

Fig. 45 (Case 13, No. 8707, B. U. I.).—Specimen removed at operation.

area. There was no ulceration. The right ureteral orifice was normal. A catheter was introduced into the right kidney easily. Urine from the right side showed pus and colon bacilli but no tuberculosis. The phenolsulphonephthalein output, intramuscular, first half hour, was 40 per cent.; second half hour, 20 per cent. The patient was to have irrigations and instillations.

February 19: The patient had been under treatment by hydraulic distention and instillation of mercurochrome. His symptoms had improved greatly. The bladder capacity was 125 c.c. There was no recurrence of genital tuberculosis. The patient was discharged.

CASE 14 (No. 8729).—*History.*—B. A. R., aged 30, married, admitted, April 24, 1920, complained of swelling of the right testicle and pains in the back, hips, legs and buttocks. He had had gonorrhea two and a half years previously, which lasted four months, with no complications. Two years previously, while riding a horse, he lost his footing and badly bruised his right testicle against the saddle. For several days after this, the patient had considerable pain in the testicle and pain in the glands of the groin for two months. Later, he was kicked in the back by a horse. Since then, he had had rheumatism and arthritis, involving the left thigh and leg.

On admission, the patient complained of rheumatism which extended down the back of the left leg, along the outside, to the foot and toes. He had practically no pain in the testicle, epididymis or groin. Urination was free and painless. Intervals were slightly increased, from one to two at night, from six to seven times during the day. Sexual powers were normal. He had intercourse about five times a week. Ejaculations were normal; there was no blood. He had lost 14 pounds (6.3 kg.) in weight during the past two months. He had had no cough and examination of the chest was negative. Roentgenograms of the spine had been negative. The Wassermann reaction was negative. On account of the pain, above described, he had taken codein, ½ grain (0.03 gm.), daily for ten months. He was unable to walk.

Examination.—The lungs showed a few fine râles at the left apex, posteriorly, and slight dulness; diminished breath sounds and harsh breathing in both interscapular regions. It gave one the impression of fibrosis. The heart, abdomen and kidneys were negative (Fig. 46). The penis was negative. The left testicle, epididymis, cord and groin were negative. The right testicle was normal in size but rotated. The epididymis was considerably enlarged, very hard, irregular and nodular throughout its entire extent. There was no fluctuation and no sinuses. The right vas deferens was hard, nodular and enlarged. The prostate was broader than normal; the median furrow and notch were wide and deep; the right lobe was prominent, globular, slightly irregular and moderately indurated, particularly at the upper end and externally. Running upward and outward from the prostate were adhesions. The left lobe of the prostate was similar to the right, with adhesions running upward and outward. The right seminal vesicle was soft, indistinct, apparently not enlarged or indurated. The left seminal vesicle was also apparently not enlarged or indurated. Neither vas deferens was palpable. The urine was clear, acid in reaction; the specific gravity was 1.018; there was no albumin, no sugar, no casts. Microscopically, it showed pus in small amount; no bacteria were seen; tuberculosis was sought for. The phenolsulphonephthalein test gave these results: appearance time, ten minutes; 60 per cent. for the first hour and 20 per cent. for the second; total 80 per cent. Roentgenograms of the chest, kidneys, bladder and hips were taken. Outlines of the kidneys were plainly seen, apparently negative. The vertebrae were negative. The chest showed fibrosis of both upper lobes. The hips were negative.

The impression was tuberculosis of the right epididymis and prostate, probably of the seminal vesicles and vasa deferentia. Radical operation was advised.

Operation (Young).—May 7, under gas and ether, a radical operation (Fig. 47) was performed consisting of :(1) perineal excision of both lobes of the prostate, right seminal vesicle, ampulla of right vas deferens; the urethra and bladder were not opened; (2) epididymectomy, right side, complete removal of the vas deferens by traction, through scrotal wound. The testicle was normal. A small area was removed; the rest was left intact. Both wounds were

drained. Both lobes of the prostate were found to be very hard and considerably enlarged. The right vas and right seminal vesicle were hard and irregular, and yellowish material was seen shining through the fibrous cavity. The vas was divided about 7 cm. above the prostate. The prostate and seminal vesicles were evidently tuberculous.

Pathologic Report.—Extensive tuberculosis of the right vesicle, right vas, both lobes of prostate and right epididymis was reported.

May 22: Two weeks after operation, there were no complications; no urethral leakage. The testicular wound was healed by first intention. The perineal wound was healing by granulations. The patient was much improved in health and was now able to walk; whereas before operation he was unable to do so. He was discharged. The general condition was excellent.

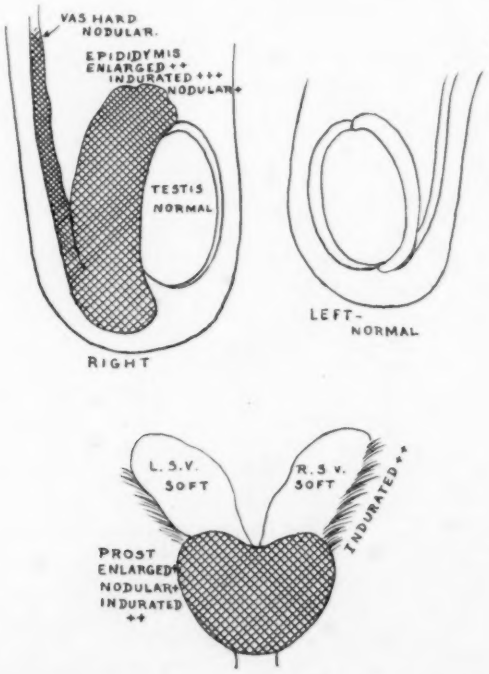

Fig. 46 (Case 14).—Clinical diagram; induration apparently confined to prostate. At operation the right vesicle was found to be tuberculous.

June 22: The patient reported that he was operated on two weeks previously for acute mastoiditis, considerable pus having been evacuated. He still suffered from rheumatism. The result of the genital operation was excellent.

March 5, 1921: A letter stated: "My condition is improved and I do not suffer so severely. My back is rigid and I can use my left leg but little without the aid of crutches. (Before operation could not walk at all.) I have three places discharging pus, viz., from my ear, from the cartilage where the ribs join on my breast and from my left foot; the breast was lanced about eight months ago and the foot about two months ago."

Case 15 (No. 5430, B. U. I.).—*History.*—N. D., aged 33, widower, admitted Dec. 2, 1920, complained of swollen, painful left testicle and pain in the groin,

and painful defecation. In 1911, at the age of 24, he had had gonorrhea, complicated by left epididymitis from which he apparently recovered. Several months later, he suddenly had swelling and pain in the right testicle. After that he suffered, off and on, with pain in both testicles. Four years previously (age 29) he began to have pain in the bladder and frequent and painful urination. He was admitted to this hospital, Oct. 7, 1916, complaining of pain in the right hypochondrium. Cystoscopy and ureteral catheterization were performed and pyelograms were made; all were negative. Careful search for tuberculosis was made but none was found. The diagnosis was pyelitis. He was discharged,

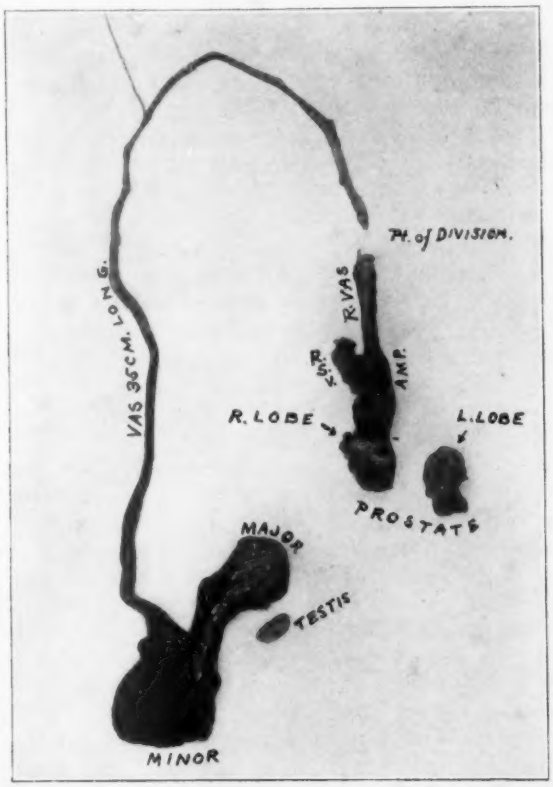

Fig. 47 (Case 14).—Specimen removed at operation.

October 26. He was readmitted, December 8, again complaining of pain in the right side. Tubercle bacilli were found in the urine from the right kidney.

Operation.—Right nephrectomy was performed, Jan. 8, 1917. Convalescence was uneventful. Pathologic examination revealed tuberculosis of the right kidney. He was discharged, February 8.

In May, after an injury to the right testicle, an abscess had formed which was opened by operation. The patient was admitted again, July 7, complaining of frequent and painful urination. Examination revealed right tuberculous epididymitis with fistula. Right epididymectomy was performed. Microscopic diagnosis was tuberculosis. He was discharged much improved, August 3.

August, 1920, he developed swelling and pain in the left testicle and epididymis, which had persisted up to the present time.

Examination (October 20).—The patient was thin. The breath sounds were harsh all over the chest, especially both apexes. No râles were elicited. The heart was negative. There was a scar on the right side of the abdomen from a previous nephrectomy. The left kidney was apparently negative (Fig. 48). The penis was negative. The right epididymis was absent. The right testicle was apparently normal. There was no sinus. The left testicle was normal; there was slight hydrocele. The left epididymis was greatly enlarged throughout and very hard with no areas of fluctuation and no sinus. The vas was nodular and indurated. The prostate was indurated on each side, soft in the middle, not enlarged. Induration also ran across the upper edge of the prostate and continued upward, involving both seminal vesicles and tissues between them. The induration was considerable and obscured the seminal vesicles and vasa deferentia, extending at least 4 cm. above the prostate. Urine was slightly cloudy, acid; specific gravity, 1.004; pus cells few. Microscopically, bacilli but no tubercles were found. Phenolsulphonephthalein test: appearance time, fifteen minutes; first hour, 45 per cent., second hour, 10 per cent.

Operation (Frontz).—October 25, under gas, oxygen and ether, a radical operation was performed (Fig. 49). Through the perineum, both seminal vesicles and ampullae and a portion of each lateral lobe of the prostate were removed, without injury to the bladder, urethra or rectum. Through the scrotal incision, the left epididymis was removed and the vas deferens was removed completely by traction through the wound. The testicle was not removed. The mediastinum testis was involved. Both wounds were closed with drainage.

Pathologic Report.—The epididymis, both seminal vesicles, the ampullae and portions of the prostate were removed. They showed extensive tuberculosis.

Course.—October 29, sudden fever (103 F.) and pain in left side developed. Diagnosis was pyelitis. Under forced "fluids," the temperature finally became normal and on discharge, December 2, the patient was in excellent condition The wound had healed. He voided urine at intervals of every two hours without pain. His general health was much improved.

Feb. 16, 1921: A letter from his physician said: "Patient voids twice at night and three times during day. Urine clear microscopically. The left side of scrotum contains a hard nodule at the seat of the operation. He now complains of some stomach trouble, but on the whole for a man who has tuberculosis of the urinary tract, he is in very good condition."

VI. ANALYSIS OF THE FIFTEEN RADICAL OPERATIONS ABOVE DESCRIBED

The fifteen radical operations described above have been studied by analytic tables, and in order that the reader may get a better comprehension of the operative results and the pathology, these tables are reproduced herewith.

The previous histories and the accompanying tables have given such a complete idea of the cases in which this radical operation has been carried out that hardly any additional comment seems necessary.

A Discussion of Pathology and Technic.—The tissues removed at operation were: right seminal vesicle 10 (alone 2); left seminal vesicle

13 (alone 5), bilateral 8, unilateral 7. Of these 7 cases of unilateral excision of the seminal vesicles and ampullae, 3 subsequently developed tuberculosis of the remaining epididymis, the other epididymis having been excised with its corresponding ampulla and vesicle at operation. This would seem to be an argument for routine double vesiculectomy.

In all cases, the seminal vesicles removed were thought to be involved, but not proved in one case.

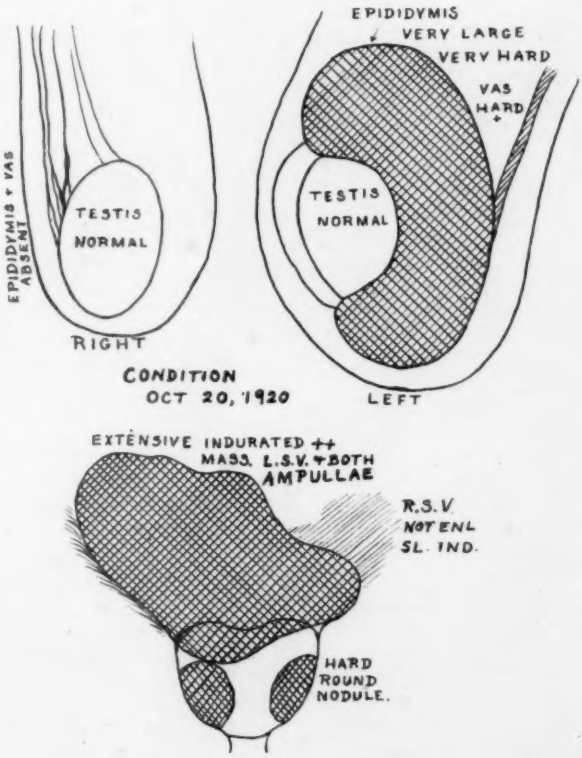

Fig. 48 (Case 15).—Clinical diagram after right epididymectomy, and before radical operation.

The ampullae removed were: right 10; left 13; both 8. (Same as with vesicles, above).

The vasa deferentia were removed as completely as possible with the epididymis and in all but about three cases the vas came away completely, often showing the teeth of the clamp on the lower end. In one case in which the vas did not come away completely, there was an extensive retrovesical tuberculosis which involved the vasa deferentia (Case 7).

Other similar, but less extensive, cases have been seen. Before clamping and dividing the vas, it is well to free it as high up as possible back of the bladder, remembering to avoid the ureter and peritoneum.

Both lateral lobes of the prostate have been removed in ten cases and the left lobe alone in three of the other five cases. In two cases the excised prostatic tissue was found to be not tuberculous on either side. The urethra was not opened in any case by the excision of the lateral lobes, and the fact that only one of the patients has a urinary

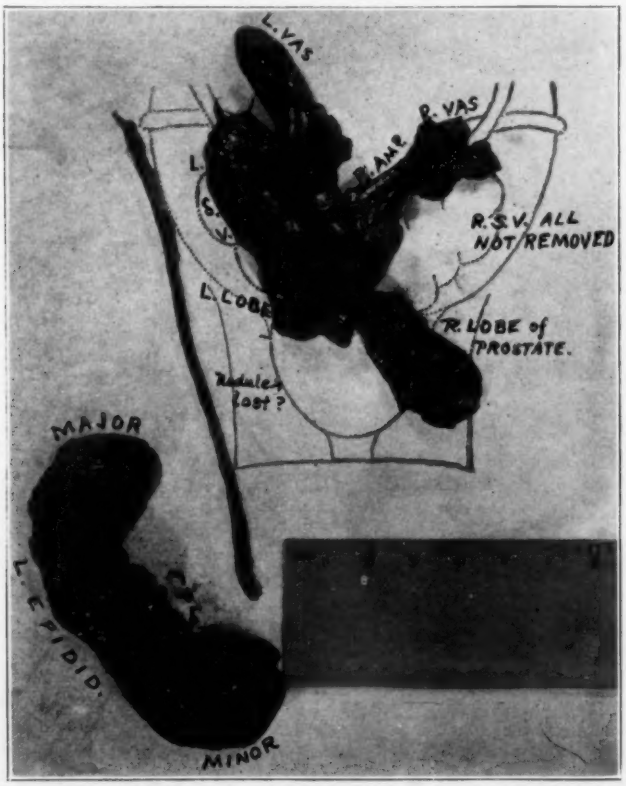

Fig. 49 (Case 15).—Specimen removed at operation.

fistula shows that it is a safe procedure. The severe tuberculous involvements which have been encountered in many cases show the advisability of prostatic resection.

The deeper portion of the vas deferens—the ampulla—was apparently involved in all specimens except one. On the right side ten ampullae were removed, eight positively tuberculous, and two probably tuberculous (sections not proved microscopically). On the left side, thirteen were removed, ten positive, two probable, only one positively

not tuberculous. In many instances, the tuberculous ampulla formed a larger mass than the adjacent vesicle.

The remainder of the vas deferens which was extracted by traction through the groin contained no definite areas or nodules of tuberculosis in six out of twenty-two vasa removed. The upper and lower ends were the portions most frequently involved, and in several cases were associated with exclusive perivasal tuberculosis of the retrovesical tissues. Our findings surely prove that forcible evulsion of the vas from the groin, without removal of the ampulla and vesicle through the perineum, is a very dangerous procedure and bad practice. As a rule, no difficulty is experienced in extracting the entire vas deferens from a wound in the upper part of the scrotum, by to-and-fro traction, with the assistance of a clamp in the perineal wound, as described in the technic of operation. It is useless and harmful to open up the inguinal canal, and especially to follow the vas into the pelvis as in the Villeneuve technic or the modification practiced by Whiteside, who has admitted, in his more recent papers the bad results obtained by Villeneuve's inguinal method.

The epididymides were removed twenty-four times, thirteen left and eleven right. All were definitely tuberculous, but in two cases on the left side the globus minor alone was involved. In the other twenty-two epididymides, the entire epididymis was tuberculous. No case of isolated globus major tuberculosis was found—an interesting fact as regards etiology.

Eight complete castrations were performed (three left, five right; only in one case were both testicles removed). In four instances, excision of the upper posterior part of the testicle next to the epididymis was carried out, and tissues excised were found to be tuberculous. None of these cases have required complete castration, although all have gone more than a year. Of the eight testes removed, all but two showed only a limited area of involvement in that portion of the testis near the globus major of the epididymis. Only one presented extensive caseation of the entire testicle. In only one case was double castration carried out; and in this case, lung tuberculosis was present and operation was performed quickly under procain (Case 12).

These cases, therefore, show that involvement of the testis is comparatively rare and that in most cases a partial excision is sufficient to remove the entire tuberculous area. This should always be attempted in bilateral involvement of the testis. In our one such case, the bad condition of the patient and our desire to avoid a long operation (epididymectomy) under local anesthesia caused us to perform a double castration (Case 12).

Nephrectomy was performed three times (kidneys removed being all markedly tuberculous, two patients having been operated on before

radical operation on the seminal tract, one after). In one case, tuberculosis was found by ureteral catheterization of the right kidney. The patient is healthy and strong. The involvement is probably small and quiescent (Case 1). Another patient (Case 10) had a tuberculous right kidney, which has remained quiescent.

The lungs were considered involved in seven cases, all but one apparently quiescent; and six patients have done well since operation. The other patient (Case 2) died of mediastinal tuberculosis one year later. Whiteside advises against operation in cases with lung involvement. This is certainly wise if the lung involvement is active and extensive. When pulmonary cases become quiescent, however, I agree with Kocher that the genital tuberculosis should be removed; and I go further than Kocher in advising excision of the seminal vesicles as well as the epididymides or testes. The radical operation can be performed under procain infiltration anesthesia (1 to 400) with only a whiff of nitrous oxid gas occasionally to quiet the patient; or it can be performed under spinal, or posterior nerve root anesthesia. In reality, nearly all patients whose cases are not hopeless should be given the chance to get well. Whiteside has shown that desperate cases may sometimes be cured by vesiculectomy.

To reiterate, the pathologic study of these fifteen cases shows conclusively the preponderant importance of the seminal vesicles as the primary seat of the disease, and the urgency to remove them if radical cures are to be uniformly expected, and the present disgraceful mortality in genital tuberculosis is to cease.

B. Immediate and Remote Results of These Radical Operations.—The operation has not been reserved entirely for patients in good general condition as shown by the fact that seven patients had fairly definite evidence of tuberculosis of the lungs previous to operation and five patients had tuberculosis of the kidney, three requiring nephrectomy. Regardless of this fact, there has been only one death so far recorded, going back as far as seven years; and all but one of the cases have been followed almost a year at least. Perineal urinary fistula, that supposedly great bugbear of operations on the tuberculous prostate and vesicles, is present in only one case; and in this, only a few drops of urine escape during urination, so that the condition is not serious. Discharging sinuses are present either in the scrotum, groin or perineal wound in six cases. Most of these are recent cases and statistics show that they usually cease spontaneously with time. At any rate, they are not really annoying and compare favorably with statistics following epididymectomy or castration in which a much higher percentage of, and more annoying, discharging sinuses are recorded in the literature. Another most interesting demonstration is the fact that the sexual powers are not usually impaired in any way

except that the amount of ejaculatory fluid is much lessened. We have no direct evidence that any case has been impaired, though ten patients have not answered this question either before or after operation. Other operators, however, have shown that the removal of both seminal vesicles and vasa does not impair the sexual appetite or act. In three cases (Cases 2, 3 and 12) in which the vas, vesicle and epididymis on one side only were removed, the opposite epididymis became involved in the course of a year and required removal; and one patient died after the second operation (epididymectomy, one year later). Bilateral vesiculectomy was carried out in eight cases and bilateral epididymectomy or castration in eight cases; in three cases above referred to the second operation being performed later. (In these cases bilateral seminal vesiculectomy should have been done.) It may be found with time that it is wise always to remove both vesicles and ampullae and, if this is not done, either to ligate and divide the supposed healthy vas, which is not removed, or to remove the ampulla on that side, or to ligate the vas through an incision in the scrotum so as to avoid involvement of the second epididymis.

There has been one death, and that one year after the radical operation. On first admission of this patient (Case 2), râles were present in the lungs; and shortly afterward, fever, night sweats and abscess of the chest wall developed. Only one seminal vesicle was removed and the remaining epididymis developed tuberculosis, which was excised one year later. Death from extensive tuberculosis of the lungs, mediastinum, chest wall and shoulder occurred several months later. Removal of both seminal vesicles when the first operation was performed would probably have prevented involvement of the remaining epididymis, and possibly have given the patient a chance to recover from the lung tuberculosis. This case (Case 2) and two others (Cases 3 and 12) furnish excellent arguments for always excising both vesicles and both ampullae at every radical operation—especially as their excision does not destroy the sexual powers.

Two patients refuse to answer letters and questionnaires, which are not returned, indicating that the patients are still alive (Cases 2 and 4). I believe the results obtained in both of these cases were good.

Of the twelve cases in which the ultimate results have been obtained up to date, the radical operation has been eminently successful in improving the general health (even in Case 14 with previous generalized tuberculous arthritis). One of these patients developed tuberculosis in the remaining epididymis and required epididymectomy. In all cases, there has been ultimately an excellent local result, with improvement in micturition even in those cases with tuberculosis of the bladder and kidney (three of which were removed).

Considered, therefore, from every standpoint, the results obtained by the radical operation in these fifteen cases have been eminently satisfactory and far better than we have obtained by mere excision of the epididymis or testicle.

VII. DISCUSSION OF RADICAL OPERATIVE TECHNIC

In my paper [15] on this same subject in 1901, the various operations for the excision of the seminal vesicles were classified thus:

1. Perineal method of Zuckerkandl by Ullmann..... 1889
   Perineal method of Roux 1891
   Perineal method of von Dittel by Schede..... 1893
   Perineal method of Guelliot 1895
   Perineal method of Baudet 1898
2. Sacral method of Kraske by Schede..... 1895
   Sacral method of Rydygier by Schede..... 1895
3. Inguinal method of Villeneuve..... 1891
4. Suprapubic, rectovesical, extraperitoneal method of Young (20)..... 1900

At that time, thirty-four cases were to be found in the literature in which radical operations for tuberculosis of the seminal vesicles, associated with testicular disease, had been performed by one of the methods above indicated. The summary of the tissues removed was:

Part Removed.—One testicle (or epididymis), twenty-three times; both testicles, five; one seminal vesicle, twenty-three; both seminal vesicles, eleven; portion of prostate, five.

Immediate Results.—Good, no fistula, thirteen; fistula but otherwise good result, fourteen; in bad condition, two; not mentioned, three.

Ultimate Results.—Twenty cases, five deaths, ten well, four recurrences. Only eight cases were followed for more than one year; of these two died of pulmonary tuberculosis and four were cured.

Writing in 1906, Baudet and Kendirdjy,[16] in a most extensive article, detail at length the cases which are to be found in the literature and discuss the methods of operation, from which I shall extract liberally: There are two methods, the upper route and the lower route. The lower route comprises median perineotomy; ischiorectal perineotomy; the sacral method and the parasacral method. The upper route comprises the inguinal; the lateral laparotomy and the median extraperitoneal laparotomy. The inguinal is suitable only for one vesicle; if you wish to operate on two vesicles, it is necessary to perform two operations. The same applies to the lateral subperitoneal laparotomy. The median extraperitoneal laparotomy, which was described by the author and carried out in three cases, has since been abandoned on account of defective drainage and resultant severe infections.

15. Young, H. H.: Ann. Surg. **30**:601, 1901.
16. Baudet and Kendirdjy: Rev. de chir. **34**:380, 1906.

The perineal method is unquestionably the method of choice and it will be interesting to examine into the various technics which have been followed.

The first operation was that of Ullmann[17] of Vienna in 1899. Ullmann's patient was operated on in two stages—unilateral castration was carried out on the right side in June, 1889, and a month later the seminal vesicles were removed by the similunar perineal incision with the assistance of the finger in the rectum. After sectioning the fascia and the levator ani muscles, the prostate was completely exposed; and then, by introducing a metal sound into the bladder, the posterior wall of the bladder was made prominent by pressure. By this maneuver, the vasa and vesicles were easily removed. The vas deferens between the ampulla and groin was not extirpated; but a portion of the prostate which was tuberculous was excised.

Roux[16] performed his first operation in March, 1890, and subsequently he had two other cases. His procedure consisted of castration with high division of the vas and then extirpation of the seminal vesicle from below, which was made to appear in the upper portion of the wound by the pressure of the finger in the rectum, with the patient lying on his side—the incision extending in a curve across the perineum backward to one side of the rectum. With the use of a traction ligature, the vesicle was drawn farther down, separated, and with the stump of the vas deferens was divided close to the neck of the bladder. The remainder of the vas deferens, i. e., up to the inguinal canal where previously divided, was then removed with the seminal vesicle.

Weir,[18] in New York, was the third to perform seminal vesiculectomy in 1892. Weir carried the scrotal incision up into the groin and opened the inguinal canal, where he freed the vas as high up as possible on the right side, making a tear into the peritoneum in so doing. Then, leaving the testicle free and suspended by the vas, he placed the patient in the lithotomy position and carried out the operation of Roux, exposing and separating the seminal vesicle and extirpating the diseased portion of the prostate. The vas deferens was divided above the ampulla and the remainder of the vasa deferentia was removed from the front with the testicles (thus differing from the operation of Roux who removed the remainder of the vasa from below with the vesicle).

Schede,[16] in 1893, successfully removed both tuberculous seminal vesicles and vasa through the incision of von Dittel in a patient who had previously been castrated on both sides.

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17. Ullmann: Centralbl. f. chir. **8**:133, 1899.
18. Weir: Med. Rec. **44**:163, 1894.

Guelliot,[5] in 1895, published two cases in which he had removed the testicles through a scrotal incision and the seminal vesicles through an incision which began in the perineum and extended along the right border of the anus to the median line back of the anus, by means of which he was able to push the anus and rectum out of the way.

Baudet and Kendirdjy,[16] in 1898, used the following technic: A curved incision in the perineum extending farther back to the right than to the left, exposure of the prostate and seminal vesicles after division of the levator muscles; separation and division of the vasa deferentia above the ampullae after ligating the lower end; division of the vas and vesicle "in the interior of the prostate," a caseous nodule of which is removed. Right castration was then performed, the inguinal canal being opened and the vas deferens followed deeply and completely removed.

Practically all of the operators who have been referred to divided the levator ani muscles and deep lateral structures in exposing the seminal vesicles. In order to facilitate the removal of the seminal vesicles, various methods have been employed. The first is that of Ullmann who uses a sound in the bladder to make pressure on the posterior wall and thus elevate the vesicles. Others caught the prostate with toothed forceps. Roux [16] employed a finger in the rectum, which was passed up above the vesicles and by pressure brought them down into view. Subsequently, he employed, in addition, traction sutures (which have since been advocated by Squier in this country). Most operators have divided the vasa deferentia as high up as possible in the perineum, ligated and divided the upper portions of the seminal vesicles and freed them from the bladder by dissection from above downward. Legueu [16] carried out the opposite procedure, namely, division of the vesicle and vas at the upper end of the prostate and separation of these structures from the bladder by dissection from below upward. In 1913, I [3] devised an unusually long, slender prostatic tractor which could be passed through the urethra and utilized first to expose the membranous urethra and prostate in the early dissection through the perineum and subsequently to draw down the seminal vesicles and facilitate their exposure and excision, without division of the levatores ani, and without insertion of a finger in the rectum, using both traction and leverage.

In discussing the removal of the vas deferens, Baudet [16] says that it is indispensable to open the inguinal canal up to the peritoneum, to isolate the vas and liberate it well into the pelvis in order to extract it. He also thinks it is better to commence the operation from the perineum, remove the seminal vesicles and ampullae and then extricate the rest of the vas with the testicle from above. The vas can be drawn out easily without opening the inguinal canal.

A. Results Obtained by Radical Operations.—Baudet's analysis of forty-six cases, which he collected from the literature in 1906, is as follows: The inguinal method was used in six cases. Two patients died within a year after the operation—one of meningitis and the other of tuberculosis of the lungs. Two were well one year and three months after operation. In one case, two months after operation, the wound was in a bad condition being involved in the tuberculous process. One patient was well on discharge, but was not followed afterward. Three patients were operated on by the median subperitoneal laparotomy method—all bad results. The operation was condemned by the author in a subsequent publication. The sacral method was used in two cases; both patients recovered from operation and were discharged in good condition, but not followed afterward. The parasacral method was used in five cases; one with very bad wound healing, four left in good condition. None were followed after discharge from the hospital. The perineal method was used in thirty cases, with these results: well on discharge but not followed afterward, ten; deaths, four; four years, two and one-half years and five months, respectively, of lung tuberculosis, and after six months of tuberculous meningitis; well, sixteen cases, ten of which were followed for more than one year. One patient died four years later of apoplexy. With the exception of the median extraperitoneal laparotomy method, there were no immediate operative deaths during the stay of the patients in the hospital in forty-three cases. In fifteen of forty-five cases, the prostate was found to be involved.

The results found in the thirty cases in which the vesicles were removed through the perineum (the testicle, epididymis and vas through the groin or scrotal incision) are, indeed, very good; and, although this list comprises many different procedures, the results obtained are certainly better than have been secured even in more recent times by castration or epididymectomy alone without operation on the vesicles. Regardless of this fact, Baudet took a very conservative attitude—that the operation of vasovesiculectomy should be reserved for severe cases with either very marked involvement of the seminal vesicles or with tuberculous perineal fistulas. But he remarked that the presence of tuberculosis elsewhere than in the lungs (if not marked) did not contraindicate operation in these cases. Roux, on the other hand, considered that vasovesiculectomy should be performed as a prophylactic operation against involvement of the other epididymis and generalization of the tuberculosis.

At the Société de chirurgie de Paris, October 13 and Nov. 17, 1909, Baudet [19] presented two cases of vasovesiculectomy for genital

19. Tr. Soc. de chir. de Paris, Oct. 13-Nov. 17, 1908. Rev. de chir., 1909.

tuberculosis, in one of which removal was accomplished through the combined perineal and inguinal method and in the other entirely by the inguinal method of Villeneuve, with good results. In the discussion which followed, Marion presented his conclusions as to the problems as follows:

> Vesiculectomy is a legitimate operation which deserves current usage. It relieves foci of tuberculosis dangerous for the general health and menacing to the urinary and remaining genital organs. Results of the operation, when scientifically carried out, are good in the great majority of cases. Lesions elsewhere, not due to the genital lesions alone, are contraindications; but nevertheless cystitis aggravated by tuberculosis of the testicles is not a contraindication. The perineal route should be employed always when there is a double vesiculitis or vesiculitis and prostatitis and when there are data as to the lesions or the single vesicle is large. The inguinal route should be reserved for single vesiculectomies, slightly involved and clearly unilateral.

In my experience this is almost impossible to determine before operation.

Legueu agreed with these statements of Marion; but he stated that he would reserve the operation for more severe cases which were markedly aggravated.

B. Review of the Results Obtained by American Operators.—This may be divided into two stages: early operations (before 1902), Weir,[18] one case; Fenger,[20] one case; Walker,[21] one case; Bolton,[22] three cases; Young,[23] three cases; Hutchinson,[24] one case. After that there was a quiescent period in the American literature when Whiteside's [11] article appeared in 1910, in which he reported two cases with excellent results in patients who were in desperate condition. The technic followed by Whiteside is to start with the incision in the inguinal region, the vas being separated as high as possible in the inguinal canal, clamped and divided, and the testicle and outer portion of the vas being removed. The patient was then placed on his back and through a perineal incision the seminal vesicles were exposed and freed. In order to remove the remaining vas, the finger was pushed as far as possible into the depths of the retrovesical wound; then by "pushing upward on the forceps which had been previously clamped to the cut end of the vas deferens in the inguinal canal," it was possible to push this clamp through into the perineal wound, carrying the cord with it. By removing this anterior clamp and replacing it with another through

20. Fenger, cited by Senn, N.: Tuberculosis of the Genito-Urinary Organs, Male and Female, Philadelphia, 1897.

21. Walker: Maryland M. J. **1**:55, 1877.

22. Bolton: Ann. Surg. **29**:106, 1900.

23. Young, H. H.: Footnotes 14, 15 and 16.

24. Hutchinson: Ann. Surg. **29**:567, 1900.

the perineal wound, the entire spermatic cord and the seminal vesicle with the right lobe of the prostate was removed. The same technic was followed in the second case which was found to be much more difficult. Whiteside [25] follows this with a second paper in 1914, in which he was able to present twenty-two cases of vasovesiculectomy for tuberculosis. In this article he states again that the operation should be reserved for very difficult cases and that he had employed it in "only the old and apparently hopeless cases." He states he has modified the technic.

> I have tried extirpation of prostate and vesicles from above (groin), but I will not try it again. The vesicles are easily exposed from above but the wound drains deeply and absolute failure followed by death within a short time from peritoneal infection or long continued sepsis in a deep, poorly drained wound is apt to be the sequel. I believe this operation offers the only hope of life to an otherwise doomed patient. In the twenty-two cases I have operated on in the past six years, I have had no immediate deaths and four eventually complete recoveries. Nine have died of pulmonary tuberculosis, three have died within a few months from local infection, six have been lost sight of—presumably they may be dead.

The fact that practically all of Whiteside's patients were in desperate condition partly accounts for the high subsequent mortality; but is it not probable that the employment of the inguinal method of Villeneuve in some of the cases, and in the others his own method of opening the inguinal canal and pushing the clamp down from it into the pelvis retrovesically with the attached vas in removing the latter, is responsible for some of his infections and death?

In his final paper,[12] in 1919, he again describes the same method of removing the vas with the assistance of the clamp through the inguinal canal into the perineal wound as above described. He then states:

> I regret that this first case is the only one of which I have certain knowledge that the remote result was successful. Several others have been under observation for months, but none for more than two years. Several have died of pulmonary tuberculosis within a year, and at least one of rapid miliary tuberculosis. As a result of my experience I strongly advise that those cases showing even slight pulmonary involvement be considered inoperable. I have operated on three or four such with disappointing results. The wounds of operation do not heal and only add to the patient's discomfort. In such cases, when vesical tenesmus demands interference, a simple cystotomy for drainage is preferable.
>
> When we contrast the result after this very radical operation and the administration of tuberculin, with the result of any equally advanced case treated with medicine or general hygienic measures, the difference in outcome is striking. On the one hand, the patients have regained health and are perhaps well; on the other, we so often see a broken down young man suffering severely and awaiting death.

25. Whiteside: Tr. Am. Assn. Genito-Urin. Surg. **9**:173, 1914.

In 1918, two articles appeared in America, the first by myself, in which I described the new radical procedure which I [3] had followed since 1914 and the second by Quinby [6] who detailed seven cases of radical excision of the seminal tract for tuberculosis according to my technic, without a single operative death and with excellent immediate results. There was no mortality in Quinby's cases, and the results obtained are indeed excellent and fully confirm my statements in regard to the effectiveness of the radical operation.

VIII. CONCLUSIONS

Statistics show conclusively that in most cases of "genital tuberculosis" the primary focus is in the seminal vesicles. Tuberculosis of the seminal tract is, therefore, the better name.

From the seminal vesicles, the globus minor of the epididymis is generally next attacked.

From the seminal vesicles, the prostate, urethra and bladder are often attacked later.

From the seminal vesicles, more rarely, the kidney may be invaded through the lymphatics along the ureter.

From the seminal vesicles by the posterior line of lymphatics, the mediastinum and the lungs may be involved.

Tuberculosis of the seminal vesicles (ampullae and prostate, if involved) ranks first in importance when a curative operation is proposed for genital tuberculosis.

Epididymectomy with injection of the vas and vesicle, as proposed by von Büngner, is preferable to simple excision, as Cunningham has shown.

Still better results may be obtained by bringing the vas permanently out of the skin in the groin for frequent injection and continuous drainage as proposed by myself in 1901, and often employed.

But with all the nonradical procedures, a high percentage of failures —ultimate infections of remote organs and death—result.

The only hope of radical cure or complete arrestation of the disease is by the radical operation—"epididymovesiculectomy," or better "excision of the tuberculous seminal tract."

This operation has already saved many otherwise hopeless cases.

By the technic described by myself, with the use of a long "urethral prostatic tractor," the urinary tract can be avoided, while the removal of vesicles, ampullae and prostatic lobes is facilitated.

The entire vas deferens can be removed by the to-and-fro traction described without opening the inguinal canal as previously done.

The incisions are comparatively small and the operation can be performed under procain infiltration anesthesia (1 to 400) if the lungs are involved.

The fifteen cases reported here (in seven of which the lungs were probably previously involved, and in five of which one kidney was tuberculous, etc.) and in which only one patient died of tuberculosis a year later, and the others are apparently completely arrested, shows the effectiveness of this radical operation.

In my opinion the only justifiable operation in tuberculosis of the seminal vesicles and epididymides is a radical excision of the seminal vesicles, ampullae (and lateral lobes of prostate if involved) through the perineal prostatectomy incision, coupled with epididymectomy and extraction of the entire vas deferens, with partial or complete castration if necessary (a rare occurrence).

The old-fashioned castration is an unnecessary mutilation and does not often cure. Radical excision of the seminal tract is the operation of choice.

RADIOHUMERAL BURSITIS, EPICONDYLITIS, EPICONDYLALGIA (TENNIS ELBOW)

A PERSONAL EXPERIENCE *

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Tennis elbow, as it has been commonly called in this country and Great Britain, or the epicondylitis of Franke, or the epicondylalgia of Féré, is a condition that is fairly common among tennis players, though by no means confined to them. The first mention of the lesion which I have been able to find was by Bernhardt, in 1896, in the *Neurologisches Centralblatt,* "On a Little Known Form of Occupational Neuralgia." He states that Remak had previously reported a case.

The most significant contributions on the subject since this article have been made by Bähr [1] in 1900, Clado [2] in 1902, Preiser [3] in 1907 and 1910, Vulliet [4] in 1909, Franke [5] in 1910, Momburg [6] in 1910, Coues [7] in 1914, and Dubs [8] in 1920. The articles by Coues,[7] in English, and Dubs,[8] in German, are the most illuminating and complete which I have seen. There has been no entirely satisfactory explanation of the exact etiology of the condition nor any convincing description of its pathology.

The onset of the typical symptoms is rarely absolutely sudden, although the symptoms are well established within a few hours after some physical exertion. The fact that the precise moment that the physical exertion which may fairly be held to have caused the trouble

* Read before the Boston Surgical Society, April, 1921.

1. Bähr: Tennisschmerzen, etc., ein kleiner Beitrag zur Pathologie des Radio-Humeralgelenkes, Deutsch. med Wchnschr. **26**:713, 1900.

2. Clado: Der Tennisarm, Progrès méd. **16**:273, 1902; abstr. Nachr. f. Unfallhlk., 1903, p. 112.

3. Preiser, G.: Der Tennis-Ellenbogen, Zentralbl. f. Chir. **34**:65, 1907; Ueber Epicondylitis humeri, Deutsch. med. Wchnschr. **36**:712, 1910; Statische Gelenkerkrankungen, Stuttgart, Enke, 1911.

4. Vulliet: L'épicondylite, Semaine méd., Paris, 1909; abstr. Ztschr. f. orthop. chir. **26**:507, 1910; Die Epicondylitis humeri, Zentralbl. f. Chir. **37**: 1311, 1910; abstr. Zentralbl. f. chir. u. mech. Orthop. **5**:81 (Feb.) 1911.

5. Franke, F.: Ueber Epicondylitis humeri, Deutsch. med. Wchnschr. **36**: 13, 420, 1910.

6. Momburg: Ueber Periostitis am Epicondylus humeri, Deutsch. med. Wchnschr. **36**:260, 1910.

7. Coues, W. P.: Epicondylitis (Franke) or Tennis Elbow, Boston M. & S. J. **170**:461 (March 26) 1914.

8. Dubs, J.: The So-Called Epicondylitis Humeri, Schweiz. med. Wchnschr. **50**:166 (Feb. 26) 1920; Ibid. **50**:187 (March 4) 1920; abstr. J. A. M. A. **74**: 1289 (May 1) 1920.

cannot often be remembered by the patient I believe to be significant, as will later appear.

The histories recount that in the course of, or following, a game of tennis, or some continuous labor, such as painting an overhead wall in an awkward position, or striking a blow with a hammer, discomfort, amounting sometimes to acute pain, is felt in the elbow region. Seeking to localize the symptoms, the patients find tenderness in the region of the external condyle of the humerus. This tenderness may be directly over the epicondyle and may seemingly be confined to this; but with careful observation, its exact location will be found to vary with different positions of the elbow: flexion, extension, pronation, and supination. In certain positions, there may be no tenderness at all directly over the epicondyle, it having shifted perhaps in right angle flexion and pronation a little mesially and distally.

The patients do not commonly seek medical advice at once. The condition is not constantly annoying; but its persistence over weeks or months and the interference which it causes with their sport or occupation lead them to seek relief.

A typical symptom, which is also annoying, occurs apart from sports and occupation. This is a sudden sensation of weakness and pain, often running down the forearm when an attempt is made to lift an object, like a glass of water or a plate or a book, with the elbow fully or partially extended and the forearm muscles, especially the extensors, set. It is hard to anticipate this inability. The water may be spilled, the plate broken, or the book dropped. It may be possible for the patient to lift momentarily a fairly heavy weight with the extended arm, without discomfort; but carrying a bag for any length of time usually produces a feeling of weakness and an ache, which may become acute.

Without treatment, the condition lasts from six months to several years, with varying degrees of severity. Even after periods of almost complete quiescence, recurrences have been common.

The physical examination of the ordinary subacute cases reveals little. Inspection at first seems to show nothing abnormal; but if the sound and the affected limbs, in a muscular patient, are placed in identical positions, for example, the hands resting on the pubes, there will be noticed a slight obscuration of the normal contours of the affected elbow, consisting of a little fulness just over the distal tip of the epicondyle and extending distally and mesially, filling up the slight normal depression over the radiohumeral joint (Fig. 1).

Palpation also at first seems to yield negative results. There is no heat and no sharply marked swelling; but over the area of tenderness, by careful examination, a feeling of increased elasticity may be appreciated. The tenderness at first seems to be sharply localized

over the epicondyle; but, in reality, it is usually slightly distal and mesial over this portion of the radiohumeral joint, and shifting slightly in different positions of flexion and extension, supination and pronation. In cetrain positions, usually extreme pronation, there may be no tenderness whatever over the epicondyle. The stereoscopic roentgenograms have been completely negative in our cases, though evidence of "periostitis" has been reported by other observers (Fig. 1, 2 and 3).

The motions are free, and when passively carried out, are painless. When a fist is made and the wrist is plantar flexed, there is pain at the seat of the lesion; but if the wrist is dorsally flexed, relaxing the exten-

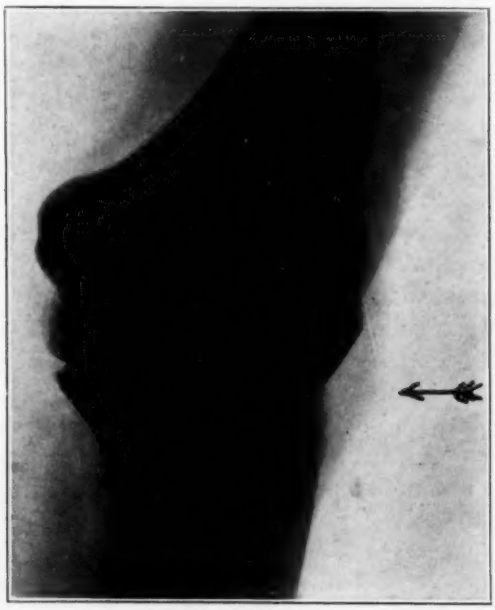

Fig. 1 (Case 1).—Anteroposterior roentgenogram of affected elbow, showing shadow of soft part swelling over lateral condyle and no evidence of lime salt deposit over the epicondyle.

sors, this pain is lessened or disappears. When an attempt is made to lift an object, with the elbow fixed in full or partial extension, especially if the hand is supinated, there is pain. In a quick, sudden extension of the forearm, as in a backhand stroke in tennis, there is often, but not always, sharp pain, ceasing quickly.

THECRIES OF ETIOLOGY

Numerous theories of etiology and the essential pathology have been advanced: (1) tearing off of certain muscular attachments to the external condyle, which are never given a chance firmly to reunite

(Coues); (2) injury to the periosteum of the condyle, with a subsequent periostitis (Blecher[9]); (3) periostitis due to postinfluenzal infection (Franke[5]); (4) injury to the radiohumeral capsule (Bähr[1] and Dubs[8]); (5) arthritis (incongruence) of the radiohumeral joint (Preiser[3]). In a recent article by Louis Carp[10] one case is reported, and after an incomplete review of the literature, he states that the etiology is still uncertain. Tavernier[11] recognizes the fact that the tenderness is a little below and mesial to the epicondyle. He has suffered from the condition himself and believes it to be due to the tearing off of a few fibers of the common extensor tendon with irritation of the periosteum; but he states frankly that this theory does not

Fig. 2 (Case 1).—Lateral roentgenogram of elbow; no lesion of bone or soft parts may be detected.

account for the persistence of the symptoms. He reports one case in which resection of the epicondyle gave relief; and he advises making an incision beneath the epicondyle and scraping the bone, as a method possibly worth trying in rebellious cases.

None of these theories of the essential pathology are entirely satisfactory in a typical case, though each may have seemed to explain the lesion in an individual patient. The syndrome commonly

9. Blecher: Ueber Roentgenbefunde bei der Epicondylitis humeri, Fortschr. a. d. Geb. d. Röntgenstrahlen **20**:239, 1913.

10. Carp, Louis: Epicondylitis Humeri, Surg. Gynec. & Obst. **32**:257 (March) 1921.

11. Tavernier: Lyon chir. **18**:257, 1921.

met can hardly be explained by one, or all, of these etiologic theories. In twelve personally observed and carefully examined cases, these hypotheses failed completely to explain the symptoms or to satisfy the physical examination.

ANATOMY

The essential anatomy of the region (Fig. 4) consists superficially of the extensor group of muscles and the brachioradialis or supinator longus which spring from the external condyle of the humerus and

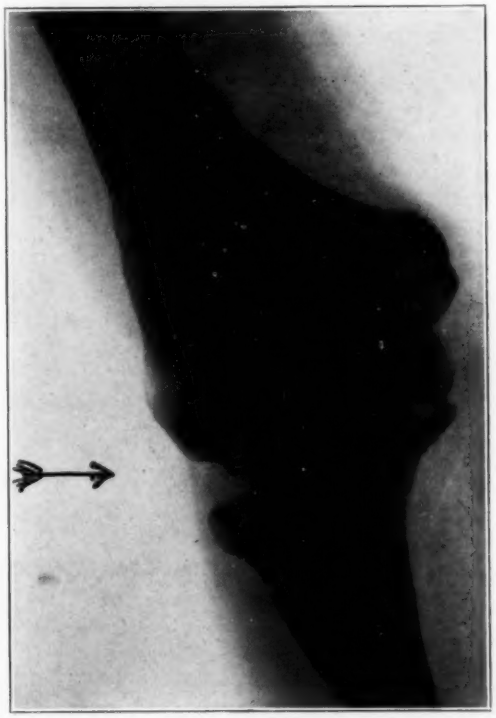

Fig. 3 (Case 1).—Anteroposterior roentgenogram of unaffected elbow; no shadow of soft part swelling over lateral condyle.

the condylar ridge above. Superficial also and most posteriorly is the considerable origin of the anconeus. Then, partially covering it, comes the extensor carpi ulnaris; next, the common extensor of the fingers and the extensor carpi radialis brevior and longior; then more anteriorly and mesially the brachioradialis or supinator longus. Beneath this conjoined tendon is the supinator radii brevis, attached to the very tip of the epicondyle with some fibers which actually blend with the radiohumeral joint. Over the supinator radii brevis and the radiohumeral joint, the conjoined tendon must have free play.

None of these muscles receive their motor nerve supply in the immediate neighborhood of the epicondyle or the radiohumeral joint. The sensory supply is from branches from the radial nerve. There are no important blood vessels directly over or beneath the conjoined tendon.

Before offering a possible explanation of the condition, a typical case will be reported. This case is a personal experience.

Fig. 4.—Muscular anatomy, showing location of radiohumeral bursa through split in conjoined tendon of extensor muscles.

REPORT OF CASES

CASE 1.—*History.*—A man, aged 48, who had played tennis for thirty-five years, and who was fond of the game, playing it hard, but in poor form, had never suffered any joint inconvenience from either handball, squash racket, or tennis. During the summer, from June to October, he had played for years, on an average, half a day once or twice a week. In July, 1920, while on a vacation and in good condition, he was playing a closely con-

tested singles set, in which no new strokes were being tried. He became conscious during the game of a dull pain on the outer side of the right elbow, the origin of which he did not remember. It did not seriously interfere with his playing. After the game, there was a slight smarting sensation in the region of the epicondyle and radiohumeral joint, no appreciable heat or swelling, rather acute tenderness to pressure, and a little pain running indefinitely down the forearm on certain motions. The initial discomfort passed off in a few hours. The tenderness remained; and he was only occasionally reminded of the existence of the lesion by a sharp, but not disagreeable, pain in various coordinated movements, most of which had to do with extension of the forearm and flexion of the fingers. This was more marked in supination with flexed fingers than in pronation.

For a few weeks, the arm was strapped with 10-inch (25.4 cm.) strips of adhesive plaster, applied with the arm in supination, running from the palmar surface of the forearm over the epicondylar surface of the upper arm, limiting full extension, and applied with the hope of relieving tension on the supinator radii brevis and brachioradialis (supinator longus). He continued to play tennis whenever the opportunity was offered, and found relief from the strapping, though this relief was not complete. His interest in the lesion having been aroused, he decided to do everything he could to make the condition worse. He removed the plaster and played throughout the remainder of the season without protection of any sort. The result was unexpected. He was never completely unconscious of the trouble during a game, and a sharp stab of pain occasionally interfered with the success of a hard backhand placement shot. In general, however, his game was not interfered with, if the scores of sets with players whose métier he had taken for several years can be taken as criteria. He even entered a small local doubles tournament, which, with the help of a good partner, he completed. Nor was this playing done with any gritting of the teeth. Service was not interfered with at all; and the occasional, momentary, sharp pain did not outlast the stroke. There frequently was a feeling of heaviness and lameness in the arm following a long match; but he was never kept awake by the pain, and the next morning he felt as well as ever. He could paddle, throw a ball, and swim without unpleasant sensations.

The condition, however, remained stationary. The tenderness continued; the discomfort was increased by carrying a heavy bag; distinct weakness was felt when the marmalade jar was passed at breakfast, and a blow over the external condyle caused an involuntary jump.

None of the theories of the nature of the lesion seemed fully to explain these symptoms. The anatomy of the conjoined tendon and its necessary movement over the supinator radii brevis tendon and the radiohumeral capsule suggested the possibility of the existence of a small bursa at this point. The chief books on anatomy were consulted but no description of a bursa in this region was found (Fig. 5).

Dr. Pearce Coues called my attention later to a description of the interosseous bursa, said to be involved in "tennis elbow," in Carl Toldt's "Atlas of Human Anatomy," Section on Myology, page 321. This bursa, however, was located at the lateral aspect of the biceps

tendon, between it and the tendon of the brachialis anticus, much too distal and mesial to explain the typical symptoms of tennis elbow, though it may explain those of the baseball "glass arm," in which the bicipital radial bursa may also be involved.

Dissections were made in the anatomic department of the Harvard Medical School, thanks to the kindness of Drs. John Warren and A. S. Begg, and a fairly well-defined, small bursa was found beneath the conjoined tendon over the radiohumeral joint (Fig. 6).

Fig. 5.—Bony anatomy, showing location of small radiohumeral bursa.

In order to discover whether this bursa was affected in my case, Dr. Lloyd T. Brown and Dr. Philip D. Wilson explored this region under local anesthesia. An extremely sensitive area was found, with outlines of a dirty, grayish-white. There was no distinct sac containing fluid. The following report of the operation was made by Dr. Pearce Coues, who was present.

Operation and Results.—Nov. 28, 1920, under infiltration anesthesia (0.5 per cent. procain) of the external aspect of the right elbow, extending from

the external condyle downward, over the head of the radius, a slightly oblique incision, 1½ inches (3.8 cm.), was made, extending from the condyle downward, in line with the radius, well over the radial head. Dissection was carried down through the fascia in this line, and the fibers of the conjoined tendon were split, after infiltration of the deeper tissues. An exquisitely tender point was located just below the condyle, on its lower surface, between it and the radial head. Incision was enlarged slightly downward, to come directly over this tender area. The radiohumeral joint was opened and exposed. It appeared normal. The radial head rotated freely. All muscle fibers seen in this region were smooth and intact. Just below the epicondyle a small

Fig. 6.—Dissection of specimen: *A*, line of skin incision; *B*, retraction of skin and subcutaneous tissue, conjoined tissue exposed, incision in line of fibers of conjoined tendon, and *C*, conjoined tendon split and retracted with opened radiohumeral bursa beneath, silk threads through walls of bursa.

amount of bluish-gray, thickened tissue was seen, which had the appearance of bursal tissue, lying directly above the anterolateral surface of the head of the radius, with fibrinous exudate on it and outside the joint. There was no free fluid found in this tissue. Two pieces of this tissue were excised for study, one from the side and one from the base of the small mass. An excellent view of the attachment fibers of the short supinator was obtained;

all muscle fibers were intact, with no fraying or thinning. Pressure over the bursalike tissue near the condyle produced the characteristic pain, sharply localized, that is complained of in these cases. The wound was closed in layers.

The pathologic report by Dr. H. S. Hartwell was chronic inflammatory tissue (Fig. 7).

The convalescence was uneventful; and within four weeks, all symptoms had practically disappeared. No tennis was played during the winter; but repeated games of handball and squash racket were played, without a return of symptoms. A heavy bag can now be carried without discomfort.

Fig. 7.—Low-power photomicrograph of portion of tissue excised from bursalike tissue found in Case 1: areolar connective tissue and fat, fibrosis and chronic inflammatory tissue.

I have refrained from publishing this paper until I had had the opportunity to play tennis through another full tennis season, so that I might determine whether a recurrence, which has been quite common in the ordinary case, would occur. There have been absolutely no symptoms of such recurrence, and I consider the condition entirely relieved.

Further dissections were subsequently carried out at the school. In one case, no bursa was found; but in seven elbows examined consecutively, bursae were present, varying in size from 1 cm. to 2.5 cm. in diameter.

CASE 2.—A typical, early case of three months' duration was encountered in the Orthopedic Clinic of the Massachusetts General Hospital in a painter, aged 41. Complete immobilization for two weeks having caused no abatement of the tenderness, the patient was persuaded to allow an exploratory operation to be performed, on the basis of the favorable outcome of the previously reported case. This case was more acute, with pain radiating down the arm and weakness of hand grip. A bursa, 2 cm. in diameter, containing a slightly cloudy, glairy fluid, resembling synovial fluid, was found (Fig. 8). The walls of this sac, which did not communicate with the joint, were curetted, and the wound was closed tight, by suturing the split in the conjoined tendon

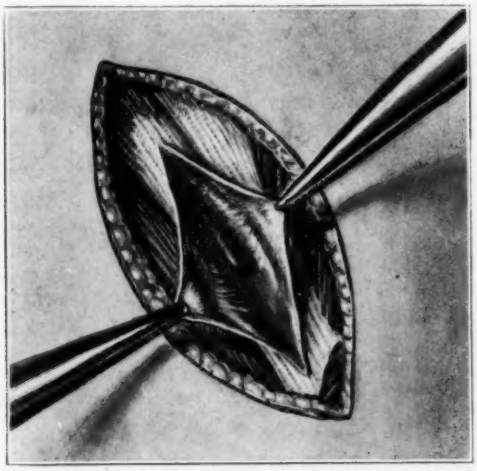

Fig. 8 (Case 2).—Operative exposure of bursa.

with catgut and the skin with silk. The arm was immobilized in plaster for one week; gentle movements were allowed during the second week, and freedom of use after fourteen days. The tenderness entirely disappeared and the patient resumed his work as a painter, without discomfort and with a full range of painless motion.

CASE 3.—*History.*—Mr. L., seen in private practice, gave a typical history of so-called tennis elbow, following a few hours after strenuous cranking of an automobile, months before. He had had no treatment other than local application; and the symptoms, though never severe, were annoying, especially in carrying a bag or lifting an object from the table. The physical signs were absolutely characteristic.

Operation and Results.—Since it was necessary for this patient to undergo a minor operation on an amputation stump of his left leg, he was advised to have the elbow explored at the same time, in the hope that the mild, but persistently annoying, symptoms might be made to subside more quickly. The

incision described in Case 1 was made, and the dissection was carried beneath the split tendon, revealing a space about 1.5 cm. in diameter, with smooth walls, but containing no free fluid. The walls of this space were curetted and a bit of the wall excised. The immediate convalescence was uneventful and the tenderness disappeared. He could lift an object without pain and could grip with the wrist in flexion without disagreeable sensation. This patient's symptoms subsequently recurred slightly. The tenderness remained absent and flexion of the fingers with an extended wrist remained painless. Carrying a heavy bag, however, again became vaguely uncomfortable. The discomfort was, however, not enough to demand further treatment.

Pathologic Report (H. F. Hartwell).—The specimen consisted of a small fragment composed of fat and connective tissue, along one surface of which was a layer of flat cells somewhat degenerate, suggesting endothelium. There was chronic inflammation (Fig. 9).

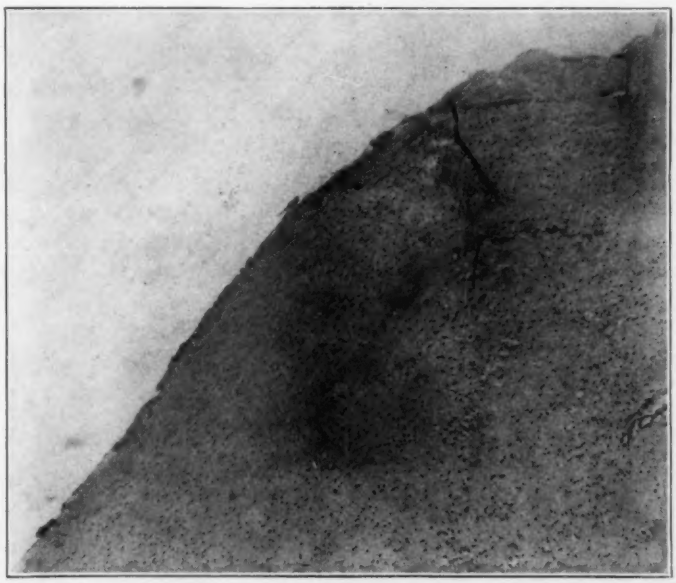

Fig. 9 (Case 3).—Low-power photomicrograph of portion of tissue excised from edge of bursa, showing fibrosis of wall and a surface strongly suggesting degenerated endothelial membrane.

COMMENT

Dr. E. A. Codman has informed me that several years ago he became interested in this condition and observed many typical cases among working men in the Outpatient Department of the Massachusetts General Hospital. He at that time suspected the presence of a bursa, but was unable to demonstrate one by dissection at the school. He discovered that he could apparently shorten convalescence by making a transverse incision over the radiohumeral joint, and he believed that he thereby relieved the tension of the fascia gliding over it, which

he supposed had set up an inflammation in the areolar tissue beneath. I believe I am right in stating that he has never published his observations, which he was kind enough to describe to me after I had told him of the bursa findings.

Another sidelight on the condition has been thrown by Dr. Wade Wright, in charge of the Clinic in Industrial Medicine at the Massachusetts General Hospital. I have considered with him about fifteen cases of pain referred to the external condyle of the humerus, occurring in connection with lead poisoning. In several of these, there had been no trauma which the patient could remember; and in several, there have been symptoms referred to the left elbow and to other joints and bursae. The association of joint pain in cases of lead poisoning has been well known for many years, the first article of which I am aware being written by Tanquerel des Planche,[12] "Lead Poisoning; A Treatise."

Dr. Wright also has been impressed with the common symptoms suggesting subacromial bursitis in cases of lead poisoning. I have examined several of these cases of pain referred to the external condyle; and the symptoms have been absolutely typical of the traumatic or occupational tennis elbow. The symptoms in several of them have disappeared along with the relief of the other symptoms of lead poisoning. This connection seems perhaps to add strength to the theory of a bursitis as the common pathologic condition.

SUMMARY

1. Tennis elbow, epicondylitis, or epicondylalgia presents a fairly typical syndrome, occurring in connection with certain sports, most commonly with tennis, and in various occupations and in lead poisoning. The right arm is more commonly affected than the left. This condition occurs more often in men than in women, but it is typical in both sexes. One case is reported in a boy of 14.

2. It seems to be most frequently caused by strenuous or repeated extension of the arm in a flexed position, meeting a sudden opposition to further extension, as in a backhand stroke in tennis, fencing or in boxing (Vulliet[4]), or by striking blows with a hammer with the arm in a cramped position, by the punching and lasting of a shoemaker, by the slinging of mortar by the mason. It is possible that an infection or toxin may be the etiologic factor in certain cases.

3. The essential pathology is believed to be an inflammatory reaction in a commonly existing bursa, varying in size, and located beneath the conjoined tendon of the extensor muscles between this tendon and

12. Tanquerel des Planche: Lead Poisoning: A Treatise, Boston, Tappan, Whittemore & Mason, 1850.

the tip of the epicondyle, the origin of the supinator radii brevis muscle, and the radiohumeral joint. Somewhat similar symptoms occasionally referred to the mesial condylar region may be explained by similar areolar tissue reactions beneath the common tendon of the flexor muscles. No constant bursa has been found in this region but adventitious ones may well occur.

4. Heretofore, the only method of treatment which has been generally successful has been complete immobilization for six weeks. Untreated, the discomfort may persist indefinitely; but it is usually self-limited, in from three months to a year. The operation of splitting the conjoined tendon, opening the bursa, evacuating the contents, and curetting its walls is not likely to do harm; and in two cases it has been followed by a rapid subsidence of symptoms and free use of the arm.

5. It is possible that the so-called epicondylitis may be due to a lesion of more than one structure, as in the operative findings of Franke [5] and Goeldel;[13] but if in the typical lesion, the bursa described above is commonly found, and if its affection, as in our cases, should be found to be fairly constant, the name radiohumeral bursitis may be considered more descriptive than the term epicondylitis or tennis elbow.

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13. Goeldel: The Causation and Treatment of Epicondylitis, München. med. Wchnschr. **67**:1147, 1920.

STUDIES IN TRAUMATIC FRACTURES OF THE CRANIAL BONES

I. EDEMA OF THE BRAIN; II. BRUISES OF THE BRAIN *

CARL WESLEY APFELBACH, S.B.

CHICAGO

I. EDEMA OF THE BRAIN

The basis for the well recognized variability of the clinical manifestations accompanying fracture of the cranial bones is readily understood when the many possible alterations in the head resulting from this form of injury are considered. There is no single anatomic change in any instance responsible for the character and severity of the symptoms. The fracture is often simple, but is produced by a force which may tear blood vessels, compress the brain, injure the content of cranial foramina or open a path for infection from the outside. The bruises of the brain that are so commonly present may be absent, and still death may follow. Similarly, extradural, intra-arachnoid (subdural) and subarachnoid hemorrhages are inconstant. Death occurring shortly after injury is probably due in some instances to shock.

Edema has long been recognized as one of the changes which may, in the brain, follow trauma severe enough to fracture the cranial bones; but the interpretation of this change, its origin and its importance as a cause of the symptoms have not received the attention given almost all other sequelae.

Some writers [1] believe that edema of the brain occurs when intracranial tension is increased by a foreign body (such as large intracranial blood clots, depressed fractures, etc.) sufficiently to interfere with the cerebral circulation. Then the capillaries and veins are compressed and stasis of blood in the arteries and veins follows, with transudation of fluid into the brain tissue. Transudation, however, does not always immediately follow such embarrassment of the circulation; frequently a period of a day or two intervenes between the injury and its appearance. The importance of edema is that it may increase intracranial pressure and aid in producing the fatal anemia of cerebral compression.

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* From the Department of Pathology, Rush Medical College.

* Aided by a grant from the American Medical Association.

1. Kocher, Theodor: Hirnerschutterung, Hirndruck und chirurgische Eingriffe bei Hirnkrankheiten, in Nothnagel: Specielle Pathologie und Therapie **5**:134, 1901. Von Bergmann and von Bruns: Von Bergmann in Handbuch der praktischen Chirurgie, Ed. 3, **1**:169-185, 1907.

Cannon [2] does not believe that fluid will pass from blood vessels into the brain tissue merely because blood pressure is increased; and he has emphasized that high blood pressure may be caused by increased tension in the brain tissue. He attributes the occurrence of edema to changes in osmotic pressure in the brain tissue, caused by contusion, the latter characterized by "diffuse formation of thrombi, punctate extravasations and thin patches of hemorrhage in the meninges"; and especially because the arteries are terminal vessels. He produced great swelling of the brain by passing physiologic sodium chlorid solution through the cerebral arteries of a cat, and concludes that edema of the brain substance is the result of alterations in the brain tissue, associated at times with a pressure many times greater than the blood pressure. He believes that the edema amply explains all the signs of intracranial tension often manifested by patients suffering from cerebral trauma.

Courtney [3] does not regard traumatic cerebral edema as a pathologic entity, but as part of a general condition that he terms "contusion," characterized by hyperemia, thrombosis and transudation. Relying on Obersteiner's demonstration of vasomotor nerves for the cerebral arteries, Courtney postulates that cerebral vascular paralysis may follow trauma as does splanchnic paralysis. Therefore, when the brain is injured and "contusion" occurs, the transudate, unabsorbed because of vasomotor paralysis, compresses contiguous regions progressively until cerebral and bulbar anemia results.

"Hirnschwellung," a condition in which the ratio that has been established between brain weight and cranial volume under normal conditions is disturbed, so that the weight of the brain exceeds the normal figure for a given cranial volume, is present in some instances of fracture of the cranial bones. Reichardt [4] believes that the pressure symptoms frequently noted after cerebral injury are due to such an alteration of that ratio. Although Reichardt, who first described "Hirnschwellung," could not find microscopic changes to explain the phenomenon, others [5] have described degenerative changes ("ameboid

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2. Cannon, W. B.: Intracranial Pressure After Head Injuries, Boston M. & S. J. **145**:158, 1901.

3. Courtney, J. W.: Traumatic Cerebral Edema: Its Pathology and Surgical Treatment: A Critical Study, Boston M. & S. J. **140**:345, 373, 393, 1899.

4. Reichardt, M.: Bericht über Folgen der Hirnverletzungen, Deutsch. Ver. f. Psychiat., April, 1918; Deutsch. Ztschr. f. Nervenh. **28**: 1905; Berl. klin. Wchnschr. **55**:822, 1918.

5. Perusini: L'anatomia pathologica in Psichiatria, Riv. sper. di freniat. **35**: 1909. Alzheimer: Beitr. z. Kenntn. d. path. Neuroglia usw., Nissl-Alzheimer hist. u. histopath. Arbeiten **3**: 1911.

glia cells and cells with fibrinoid granules"). Reichardt [6] has expressed the belief that the underlying process is absorption of water by protoplasm and not a transudate outside the cells. Attempts to reproduce this condition in animals have so far failed.[7]

Some writers [8] explain edema of the brain by changes in the rate of secretion or absorption of cerebrospinal fluid. Rawling states:

> If as a result of some head injury, the intracranial venous pressure is considerably raised, so as to be well above the tension of the cerebrospinal fluid, the normal rate of absorption of cerebrospinal fluid will be impeded and it will collect in excess.

"Reactionary swelling" of the brain to trauma is another term applied to edema of the brain by some,[9] to explain the frequent presence of excess fluid in the cranial cavity and the clinical manifestations of cerebral compression in fracture of the cranial bones.

Encephalitis and edema of the brain, following cerebral trauma, are factors which may produce a vicious circle leading to venous hyperemia, and then more edema, until anemia of the brain results, according to Garrow.[10]

Rogers [11] believes that extradural or subdural hemorrhage is never alone adequate to explain death, but that the small hemorrhages accompanied by edema (produced by "irritation") cause intracranial pressure sufficient to destroy life.

The only common factor in the above mentioned opinions is that there is an increase of fluid in the cranial cavity in some instances after fracture of the cranial bones. There still remain questions regarding edema in general which are not answered, and until they are, any discussion of the factors involved in edema of the brain must of necessity be largely theoretical.

The production of cerebral edema in vivo, simulating closely the edema found after cerebral trauma, was accomplished by Weed and

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6. Reichardt, M.: Ueber Hirnschwellung, quoted by Barbieri and Carbone: Biochem. Ztschr. **49**:293, 1913.

7. Barbieri and Carbone: Biochemische Studien über die Gehirnschwellung: (*a*) Die akute Schwellung des Gehirns und die kolloidale Lehre vom Odem, Biochem. Ztschr. **49**:293, 1913. Liesegang and Mahr: Hirnschwellung. Die Physik und Chemie der Hirnschwellung, Ergebn. d. Neurolog. u. Psychiat. **2**:157, 1912.

8. Rawling, L. B.: Cerebral Edema (Excess Cerebrospinal Fluid, Brit. M. J. **1**:499 (May 4) 1918. Hamilton, W. F.: Intracranial Pressure, Canad. M. A. J. **8**:873 (Oct.) 1918.

9. Trotter: Brit. J. S. **2**:520, 1915, quoted by Lobingier: Cerebral Edema in Intracranial Trauma, Calif. State M. J. **16**:303 (June) 1918.

10. Garrow, A. E.: The Surgical Relief of Increased Intracranial Pressure, Canad. M. A. J. **8**:882 (Oct.) 1918.

11. Rogers, C. C.: Intracranial Pressure, Surg., Gynec. & Obst. **30**:291 (March) 1920.

McKibben [12] and Renauld,[13] by intravenous injections of hypotonic solutions (water and 0.6 per cent. sodium chlorid solution, respectively).

The expression "edema of the brain" as used here represents a general edema of the brain substance and not the local edema about bruises, or edema ex vacuo, or serous meningitis, or pia-arachnoid edema or internal hydrocephalus. When edema is marked, at the postmortem examination, the drumlike tenseness of the dura after removal of the calvarium is conspicuous and commensurate with the degree of intracranial tension. After the dura is reflected from the top of the brain, the convolutions are found to be flattened; the peripheral ends of the sulci closed tightly; the small cerebral veins empty, and the larger branches near the superior longitudinal sinus sometimes filled and wedged tightly in the sulci. The minute pial arteries are almost, or quite, invisible; the surface of the visceral arachnoid layer is dry and by reflected light, scattered, almost microscopic droplets are seen that form when the viscid serous surfaces are separated. If there is no subarachnoid hemorrhage, the surface of the brain is light grayish-brown or the color of putty. When the brain is removed from the cranial cavity, it is found to be soft, and easily loses its form if laid on a flat surface. After the brain is hardened in liquor formaldehydi for several days, the following changes are noted: an increased difficulty in cutting, closure of the lateral ventricles, and the absence of the stippling of the brain substance by the small intracerebral blood vessels—a condition also usually present with anemia from whatsoever cause. Microscopically, the perivascular lymph sheaths are distended; and there are empty spaces between fibers and cells, the latter farther apart than normally. Changes in the cells are sometimes absent. In many brains, there are also the various types of bruises of the brain, leptomeningeal hemorrhage and compressed regions from large extradural or intra-arachnoid blood clots. When Weed and McKibben,[12] as mentioned, produced these changes, they also found them absent if the skulls were first trephined so the brain might expand.

Believing that information as to the water content would aid in explaining the rôle of the edema accompanying cerebral injury, determinations of the percentage of water were made of the brains from the bodies of twenty-six persons who died of linear fractures of the cranial bones and associated brain injuries.[14] (See Tables 4 and 5.)

The head of the body was opened before the trunk so as to prevent drainage of fluid from the head to the trunk and thus maintain pressure relations

12. Weed, L. H., and McKibben, P. S.: Experimental Alteration of Brain Bulk, Am. J. Physiol. **48**:531 (May) 1919.

13. Renauld, quoted by Liesegang and Mahr: Footnote 7, second reference.

14. Necropsies, medicolegal, by Dr. E. R. LeCount.

in the cranial cavity more nearly like those existing during life. The brain was removed from the cranial cavity and placed in a dry calvarium and weighed. The thin meninges were then removed from the tops of the parietal lobes; brain tissue was cut out and placed in weighed glass-stoppered weighing bottles, and weighed immediately; the material was then removed quantitatively to a beaker and kept in redistilled 95 per cent. alcohol until used.

The method employed to determine the water content is essentially that devised by Waldemar Koch,[15] modified by Mathilde L. Koch,[16] and followed by McKenzie and LeCount [17] in the study of edema of the brain following heat stroke.

The brain tissue is cut into small pieces, transferred to a dried, weighed extraction thimble and extracted in a Soxhlet apparatus for from six to twelve hours with redistilled 95 per cent. alcohol, and from six to eight hours with redistilled ether. After the ether evaporates, the dry white porous tissue is ground to powder in a glass mortar, transferred to a beaker, and digested with hot distilled water on an electric plate for fifteen minutes. The water is decanted into another beaker, and similar water digestions repeated three times. The water extracts are evaporated to about 25 c.c.; redistilled 95 per cent. alcohol is added to precipitate the water soluble proteins, and the solids are again transferred to the extraction thimble to be extracted in the Soxhlet apparatus for from twelve to eighteen hours with redistilled 95 per cent. alcohol. The alcohol, ether and water extracts and filtrates are evaporated together and dried to constant weight in a vacuum desiccator. The residue and the extraction cup are dried in an oven at 105 C. to constant weight. The sum of the weights of the dried extracts, filtrates and residue gives the weight of the solids, and subtraction of this sum from the weight of the fresh tissue gives the weight of the moisture.

Even this method does not furnish an exact measure of the water content of brains from bodies in which increased intracranial tension existed before death, for these reasons:

1. The fall of blood pressure and the passage of blood from the head to the trunk after death decrease the intracranial tension and may permit some fluid to escape from the brain tissue into the leptomeningeal spaces and even into the spinal canal.

2. When the skull-cap and dura are removed, intracranial tension is reduced; the tension on the fluid in the brain is reduced, and frequently fluid drips from the brain while the latter is being removed from the cranial cavity.

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15. Koch, Waldemar: J. Am. Chem. Soc. **31**:1340, 1909.

16. Koch, M. L., and Voegtlin, C.: Chemical Changes in the Central Nervous System in Pellagra, Bull. 103, Hyg. Lab., U. S. Public Health Service, Washington, D. C., 1916, p. 67.

17. McKenzie, P., and LeCount, E. R.: Heat Stroke with a Second Study of Cerebral Edema, J. A. M. A. **71**:260 (July 27) 1918.

3. When the leptomeninges are removed before cutting out brain tissue for weighing, fluid wells up into the sulci and frequently half fills them in the few seconds required to excise sufficient tissue.

The increase of water found by this method, therefore, represents simply some part of the actual increase of moisture in the brain that existed before death. When intracranial tension is not increased, the chance for loss of water is not so great and the determinations are more nearly correct. The smaller amount of increase found in the analyses when gray matter predominated (Table 5) may be due to the proximity of this tissue to the surface of the brain where the fluid may more easily escape.

There are several other factors entering into the analyses that may interfere with the use of the results obtained in arriving at definite conclusions as to the actual increase of fluid in the brain substance:

1. The normal water content of the whole cerebrum and of some of its components has been computed by several investigators; and it is readily understood that similar parts of the brain must be used in each analysis, and that the normal water content of such pieces must be determined for control purposes (Table 1).

TABLE 1.—NORMAL WATER CONTENT OF THE WHOLE CEREBRUM AND OF SOME OF ITS COMPONENTS

Investigator	Cerebrum, Per Cent.	White Matter, Per Cent.	Gray Matter, Per Cent.
Baumstark (Arch. f. d. ges. Physiol, Vol. 7)	.....	69.53	76.99
Bernardt (quoted by Halliburton)	.....	70.00	85.00
Petrowsky (quoted by Halliburton)	.....	68.00	81.00
DeRegibus (quoted by Halliburton)	.....	70.00	86.00
Charles (quoted by Halliburton)	81.00	.....	.....
Koch and Voegtlin [16]	76.90	.....	.....
Thudichum [7] (Die chemische Constitution des Gehirns, Tübingen, 1901)	.....	70.20	85.20
Halliburton (Chemical Physiology and Pathology, London, 1891, p. 517)	.....	70.00	83.50
Hammarsten (quoted by McKenzie and Lecount [17])	76.3	.....	.....

2. The water content of the brain decreases from infancy to old age. Rosenheim [18] found the water content, in percentage, to be 78.86 for man, 85.8 for a child of 3 months, 89.99 for a child of 5 days, and 90.29 for a fetus of 36 weeks.

3. In albino rats it has been found that the water content of the brain increases after death.[19] When death was due to pneumonia, there was from 0.7 to 0.8 per cent. more water in the brains of animals

18. Rosenheim: Purification of Kerasin and Phrenosin, Biochem. J. **8**:110, 1914, quoted by Mathews, A. P.: Physiological Chemistry, Ed. 1, 1915, p. 579.

19. King, H. D.: The Effects of Pneumonia and of Postmortem Changes on the Percentage of Water in the Brain of the Albino Rat, J. Comp. Neurol. **21**:147-154, 1911.

dead for eight or nine hours than there was in other animals examined immediately after death, other conditions being quite similar as regards age and breed.

4. After adult life is reached, the water content of brains of individuals of the same age is not the same, because atrophy is more marked in some (because of arteriosclerosis, alcoholism, etc.). Therefore, edema of some degree may be present in such a brain with atrophy and still the brain may not show by actual measurement any more water than normally present, or at the most a slight increase.

5. Murachi [20] found in experiments on swelling of the brain substance that the gray and white matters swell differently.

To decrease the errors that might result because of these factors, the water content of control brains was determined. In the first series, a piece of brain was removed from the upper surface of each cerebral hemisphere close to the motor region, cone shaped, the base being from 4 to 5 cm. in diameter and from 5 to 6 cm. deep. In such pieces, the white matter predominates. Four brains were examined with the results given in Table 2.

TABLE 2.—Water Content of Control Brains for Series 1

Case No.	Percentage of Water	Weight of Brain Tissue Used in Grams	Patient in Hospital	Time Elapsed Between Injury and Entrance	Time Elapsed Between Death and Necropsy	Age in Years	Cause of Death
21	75.83	95.6258	4 hours 25 min.	2 to 3 hrs.	10 hours	27	Bullet wounds; hemothorax, 1,795 gm. of blood*
28	75.23	97.6866	7 hours 45 min.	2 hours	14 hours	35	Bullet wounds; hemothorax
29	74.36	79.8297	Found dead	.....	Unknown	20	Bullet wounds; hemopericardium
30	75.44	129.9406	20 min.	Unknown	21 hours	45	Bullet wounds; hemothorax

* Difficulty was encountered in finding brains which could be used as controls because the water content of brains is disturbed by many causes of death. With general acute anemia, edema of the brain is present; but as the analyses show, the edema is minimal.

The normal water content for the pieces of brain used in Series 1 is near 75.5 per cent. Allowing for changes due to absorption of water after death and the variation due to age and preexisting diseases, an actual increase of water is considered to be present when the analysis indicates that the percentage of water is above 76 per cent.

In the second series, a thin piece was removed from the upper surface of each hemisphere, the thickest portion measuring not more than 1 cm. Gray matter predominates in these pieces. The material used by MacKenzie and LeCount [17] was of similar parts of the brain;

20. Murachi, N.: Ueber die titrierbare Azidität und die Quellungsfähigkeit des urämischen Gehirns, Arb. a. d. neurol. Inst. a. d. Wien. Univ. **10**:327, 1912.

and the two analyses of control brains which I made agree with their results for the normal brain. In this series, 80 per cent. of water is used as the highest limit for normal brains.

These figures for normal brains take into account absorption of water that may occur after death, since the bodies of both the control and skull fracture groups were kept in approximately the same conditions, and both contain instances in which the bodies were examined as long as twenty-four hours after death.

TABLE 3.—Water Content of Control Brains for Series 2

Case No.	Percentage of Water	Weight of Brain Tissue Used in Grams	Patient in Hospital	Time Elapsed Between Injury and Entrance	Time Elapsed Between Death and Necropsy	Age in Years	Cause of Death
31	79.80	95.5795	Found dead	.....	Unknown	21	Bullet wounds
32	79.35	75.9051	25 min.	2 hours	24 hours	40	Bullet wounds

TABLE 4.—Results and Conditions Connected with Examinations of Brains in Series 1 (Skull Fractures)

No.	Percentage of Water	Estimated Increase of Water in Percentage	Weight of Brain	Estimated Increase of Water in Whole Brain	Patient in Hospital	Hours Elapsed Between Injury and Entrance	Hours Elapsed Between Death and Necropsy	Age
5	75.01	0	1,136	0	8 days 8 hours	Few hours	3 hours	39
6	79.35	3.35	1,345	45.05	37 hours	4 hours	19.5 hours	30
7	78.04	2.04	1,326	27.05	1.5 hours	5 hours	9 hours	50
8	75.40	0	1,375	0	11 days	Few hours	24 hours	53
9	78.30	2.30	1,266	29.12	29 hours	Few hours	7 hours	40
10	75.16	0	1,339	0	33 hours	7 days	24 hours	44
11	75.85	0	1,255	0	1 hour	1 hour	12 hours	28
12	77.77	1.77	1.455	25.75	1 hour	5 to 7 hours	12 hours	55
13	75.22	0	1,289	0	2 days 8 hours	Unknown	22 hours	42
14	76.90	0.90	1,368	12 31	50 hours	1 hour	6 hours	33
15	76.97	0.90	1,280	11.52	50.5 hours	Unknown	6 hours	30
16	79.70	3.70	1,102	40.77	36 hours	1 day	4 hours	2
19	77.50	1.50	1,733	25.99	17 hours	Unknown	16.5 hours	35

In Table 4, the results and some of the conditions connected with the examinations of the brains in Series 1 are listed, and in Table 5 those of Series 2.

COMMENT

The actual increase of water for the entire brain when edema is present varies between 3 and 45 gm. Many attempts have been made to determine the volume of a foreign body that will produce symptoms or death when in the cranial cavity. Deucher [21] injected masses of paraffin into the cranial cavity of animals and found that when 6 per

21. Deucher: Ueber Hirndruck, Deutsch. Ztschr. f. Chir. **36**:145, 1893.

cent. of the brain volume was introduced no changes occurred; but with 10.1 per cent., there was slowing of the pulse and respiration. Schulten [22] believes that in man there may be from 40 to 90 c.c. decrease of intracranial space by extradural hemorrhages and no symptoms necessarily follow. Sixty-eight c.c. of free blood between the dura and the cranial bones have produced moderate stupor and slowing of the pulse; and 116 c.c. have produced marked symptoms of intracranial pressure with coma. Schulten also states that 130 c.c. of free blood in the subdural space may produce no symptoms, while 250 c.c. soon produces death. Cushing [23] states that unless some specialized centers are compromised by a compressing force, the cranial cavity may harbor a foreign body from one-eighth to one-tenth the size of the

TABLE 5.—Results and Conditions Connected with Examinations of Brains in Series 2 (Skull Fractures)

No.	Percentage of Water	Estimated Increase of Water in Percentage	Weight of Brain	Estimated Increase of Water in Whole Brain	Patient in Hospital	Hours Elapsed Between Injury and Entrance	Hours Elapsed Between Death and Necropsy	Age
1	78.74	0	1,562	0	8 hours	Unknown	12	45
2	80.9	0.9	1,327	11.94	30 hours	Unknown	20	60
3	79.0	0	1,348	0	1.40 hours	3 or 4	16	33
4	82.20	2.20	1,350	29.70	3.30 hours	10 ?	13	14
17	78.29	0	1,509	0	48 hours	Unknown	8.30	30
18	81.48	1.48	1,319	19.52	26 hours	3 or 4	20	67
20	79.39	0	1,579	0	10 hours	Few hours	5	35
22	79.30	0	1,377	0	20 hours	Unknown	9	45
23	80.71	0.71	1,295	9.19	2 hours	Unknown	14	65
24	81.86	1.86	1,333	24.79	21 hours	Unknown	4	60
25	81.01	1.01	1,391	14.04	52 hours	3 or 4	10	7
26	81.62	1.62	1,341	21.72	9 hours	2 hours	5	40
27	80.22	0.22	1,336	2.93	5 days	3 hours	16	70

brain, without the major symptoms of compression appearing. Pagenstecher [24] did not find general symptoms of compression when 6.5 per cent. of the cranial cavity was occupied by a foreign body; but with 8.1 per cent., coma and sudden death occurred.

The variance in the figures quoted is dependent on the unequal vulnerability of the various parts of the brain to pressure. Breslauer [25] produced unconsciousness in dogs by the injection of 2 c.c. of physiologic sodium chlorid solution in the subarachnoid space at the base of

22. Schulten: Arch. f. klin. Chir. **32**:433, 455, 947, 1885, quoted by Kocher: Footnote 1.

23. Cushing: Some Experimental and Clinical Observations Concerning States of Increased Intracranial Tension, Am. J. M. Sc. **124**:375-400, 1902.

24. Pagenstecher, quoted by Kocher: Footnote 1.

25. Breslauer: Zur Frage des Hirndrucks, I. Ueber akuten Hirndruck, Arch. f. Clin. Chir. **103**:478-496, 1914.

the brain, while Duret [26] was able to inject 18 c.c. of a similar solution before symptoms appeared.

Even though the actual increase of water in some of the brains examined would appear to be insufficient to produce symptoms when compared to the figures quoted above, the tenseness of the dura, after the removal of the calvarium and the absence of other foreign bodies (such as clots, etc.), suggest that edema is the cause of the increased intracranial tension. The experiments of Weed and McKibben [12] indicate that edema alone causes swelling of the brain sufficient to produce protrusion of the brain through trephine holes and cerebral hernia. Positive proof that edema plays a rôle in the production of symptoms of intracranial pressure in fractures of the cranial bones may be obtained by surgeons from clinical observations. If edema does cause symptoms of intracranial pressure, then they should usually appear several hours after the injury and increase up to the end of the second or third day, and then diminish unless death ensues. If other causes for increased intracranial tension (such as extradural and subdural clots) are absent or of minimal extent, it may well be concluded that edema may produce the symptoms of intracranial tension. Reichardt [6] and others have suggested that the increase of the volume of the brain may be due to a colloid-chemical phenomenon, based on the work of Fischer [27] and others,[28] and this may explain the marked swelling in the presence of a relatively small increase of the water content of traumatized brains.

CONCLUSIONS

1. Edema of the brain occurs frequently with fractures of the cranial bones.

2. Edema was most frequently found in the brains of persons who died between several hours after the accident and the second or third day; it was usually absent when death occurred during the first few hours or three or more days after the injury.

3. It is not yet known whether edema of the brain plays an important part in producing symptoms and death in fractures of the cranial bones, or whether it is merely a terminal pathologic condition dependent on changes in the brain tissue, physical or chemical, that are the essential lesions of traumatized brains.

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26. Duret: Etudes experimentales et cliniques sur les traumatismes cerebraux, Paris, 1878.

27. Fischer, M. H.: Oedema and Nephritis, New York, John Wiley & Sons, Ed. 3, 1921, p. 731.

28. Barbieri and Carbone; Liesegang and Mahr: Footnote 7.

II. BRUISES OF THE BRAIN

The examination of the hardened brains used in the analysis for water content revealed some characteristics of bruises of the brain and traumatic leptomeningeal hemorrhage that have not been given careful consideration in the literature that I have reviewed.

In a previous report [29] in which were described the bruises in the brains of 504 persons who died with fracture of the cranial bones, a classification of bruises was made to bring out the *extent* of the cerebral destruction. In about 10 per cent. of the 504 brains, there were deep lacerations, the leptomeninges were torn widely open, and the brain was destroyed for from 2 to 4 cm. deep, and in areas of from 4 to 6 cm. The remainder of the bruises varied from wedge-shaped regions from 2 to 4 cm. deep, the leptomeninges covering them being torn sometimes, and the brain tissue being infiltrated with blood and superficially destroyed, to smaller bruises frequently consisting merely of petechial hemorrhages of the cortex. After careful consideration of the bruises in the twenty-six brains studied in this series, still another classification of bruises presented itself. In the first class are those which result from laceration of the brain tissue at the time that the cranial bones are fractured, and in the second, a much larger group, bruises which are caused by hemorrhage from torn pial arteries at, or near, the junction of the white and gray matter. It is with the second class that this discussion is chiefly concerned.

When a hardened brain from the body of a person dying with fracture of the cranial bones is examined, the first thing usually noticed is free blood in the leptomeninges, sometimes thick enough to hide the convolutions of the brain and sometimes only enough to make the sulci brown. But common to all is the patchy distribution of the blood and the presence of the blood chiefly in the leptomeninges of the front half of the top of the brain, while at the base the surface and the margins of the bruises are covered with blood. Traumatic intraleptomeningeal hemorrhage does occur without grossly visible bruises of the brain; but much more commonly it results from cerebral injury. In view of the fact that the base of the brain is frequently injured, while the upper surface is injured infrequently, there must be distinct anatomic or physiologic conditions to explain this phenomenon. A fact that does not agree with the explanation that the leptomeningeal hemorrhage is the result of trauma to the thin meninges of the top of the brain is that the blood can usually be traced to bruises of the under surface or sides of the brain, being thickest near the bruises and gradually thinning

29. LeCount, E. R., and Apfelbach, C. W.: Pathologic Anatomy of Traumatic Fractures of Cranial Bones and Concomitant Brain Injuries, J. A. M. A. **74**:501-511 (Feb. 21) 1920.

out toward the top of the brain. Still another explanation may rest in the flow of the cerebrospinal fluid from the base toward the pacchionian bodies, which would carry the blood with it to the top of the brain. During the removal of the leptomeninges of the brain in order to determine the exact amount of bruising of the outside of the brain, it was found that the leptomeninges of the top and sides of the front of the brain are easily stripped from the surface and out of the sulci; whereas at the base, only small pieces can be removed because of the tightness with which the membranes hug the surface of the brain. Inasmuch as bleeding follows the lines of least resistance, I believe that it is the latter factor that determines the spread of the

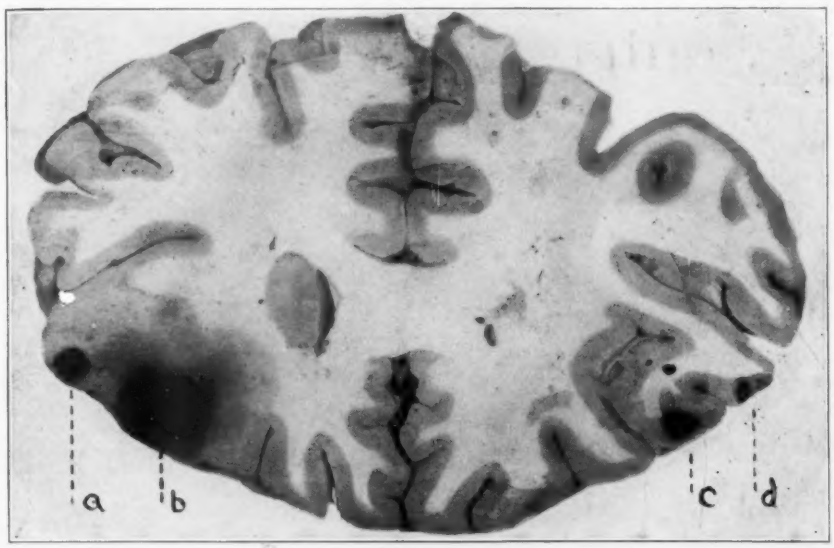

Fig. 1.—Posterior surface of a coronal segment of the cerebrum at the level of the anterior horns of the lateral ventricles: *a* and c indicate two bruises, the centers near the junction of the gray and white matter; the outside of the brain at *c* grossly is unchanged, while at *a* it is unchanged except for grayish-black discoloration. At *b* is a large bruise entirely inside the brain since there is a thin strip of gray matter at the surface. At *d* is a bruise, all in the gray matter and extending to the surface, for here there is shallow excavation, the surface honeycombed and mottled brown and gray.

blood to the top of the brain instead of into the tightly adherent leptomeninges of the base.

When the surface of the brain is examined after the leptomeninges are removed, many signs of injury are found that cannot be seen with the membranes still in place. Often when the leptomeninges are not torn and only leptomeningeal hemorrhage is seen, multiple small bruises

can be found. Aside from the larger lacerations already excluded from this description, the surface appearance of the injuries is as follows:

The minimal changes consist of gray-black discolorations of the surface, from 1 to 10 mm. in their greatest dimension. They are located a variable distance centrifugally from the largest bruises. A little more extensive, and the most frequent, type of injury is defects (Fig. 3, *c* and *b*) of the most prominent parts of the convolutions, from 1 to 4 or 5 mm. deep and from 1 to 10 mm. in the greatest surface dimension, round, oval or irregular in outline, the base being granular,

Fig. 2.—Anterior surface of a coronal segment from the left cerebral hemisphere about 5 cm. posterior to the frontal pole. At *b* and *c* are two bruises, 1 cm. from the under surface of the brain, with intact brain tissue intervening. They are both at the central end of a sulcus and near the junction of the gray and white matter. At *a* is a defect in the under surface filled by a blood clot, and there was a sulcus in the center of the clot; the defect probably resulted from bleeding which occurred from a lesion similar to those at *b* and *c*. At *d* is a laceration of the brain with additional destruction by bleeding from torn blood vessels in the surrounding brain tissue. The accumulation of blood in the leptomeninges and tearing from distention are illustrated at *e*.

discolored a light brown to gray-black, and made up of numerous, small, semispherical depressions at the bottoms of which there are frequently minute hemorrhages. The margins are slightly scalloped,

sharply demarcated, the surrounding tissue for from 1 to 3 or 4 mm. discolored a light brown to gray. Still more extensive injuries, resulting from hemorrhage, are defects (Figs. 2 *a* and 4 *a*) filled with clotted blood, from 5 to 15 mm. in diameter, the surrounding tissue intact or discolored a light brown to gray, or superficially absent, as in the second type described.

In surfaces made by sectioning the brain in the usual way, at the regions of discoloration of the outside of the brain, hemorrhages are present, from 1 to 20 mm. in diameter, separated from the surface of the brain by a layer of gray matter from 1 to 2 or 3 mm. thick. Fre-

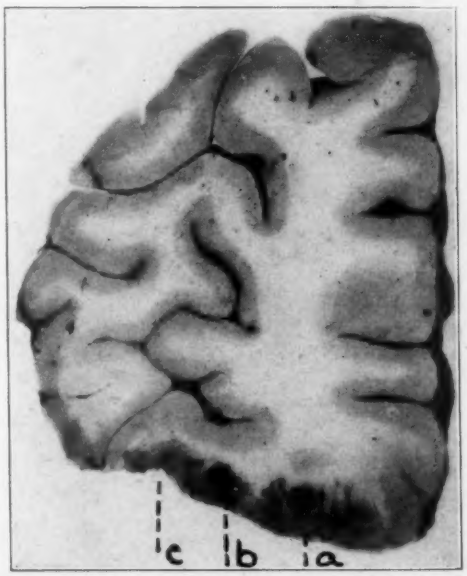

Fig. 3.—Posterior surface of a coronal segment of the left cerebral hemisphere, 4 cm. posterior to the frontal pole. Multiple hemorrhages are present in the under surface at, or near, the junction of the gray and white matter. At *a* beginning extension of bleeding from a hemorrhage is seen. At *b* the blood has already reached the surface and produced here a round, black, slightly honeycombed depression. At *c*, there is a saucer-shaped excavation, the surface honeycombed, mottled black and gray, the black spots representing the hemorrhages present in the gray matter. Smaller hemorrhages are seen with extension toward the surface in thin streaks, probably along perivascular sheaths.

quently, hemorrhages are found at the junction of the gray and white matter without any gross changes of the surface of the brain opposite them (Figs. 1 *c* and 3 *a*).

Surfaces through the bruises of the second type show small or large hemorrhages at, or near, the junction of the white and gray matter, immediately above the base of the defects. Occasionally, no hemor-

rhages are present here, and it may be assumed that the bleeding had carried with it all the brain tissue immediately peripheral to the innermost level of the hemorrhage (Figs. 3 *c* and 4 *a*).

Surfaces through the larger bruises show defects from 1 to 2 cm. deep, filled with clotted blood, the margins of which are discolored, and in the surrounding brain tissue are multiple petechial hemorrhages or simply discoloration. In the latter instance, if the clotted blood is removed, nothing more is seen than in the superficial contusions, as if

Fig. 4.—Posterior surface of a coronal segment from the left cerebral hemisphere near the anterior horn of the lateral ventricle. At *a*, in the surface, there is a round, black blood clot, 5 mm. in diameter, and about it for from 5 to 7 mm. multiple smaller black regions. A sulcus extended into the brain here. There are also multiple small hemorrhages at, or near, the junction of the gray and white matter, many of which extend into the excavation, but not shown here, because they are seen on the external surface. At *b* is a small hemorrhage beginning at the junction of the gray and white matter and extending to the surface. Other smaller, round and linear hemorrhages in the gray matter are also present.

a hemorrhage had occurred as indicated in Figure 1 *a* and *b*, and then broken through to the outside, leaving merely a cavity. In Figure 2, *a* and *d* indicate two typical bruises of this type.

I believe that these three types of bruise are merely stages of one process. In many instances of fracture of the cranial bones, the force is not sufficient to lacerate the brain, but only sufficient to tear the small arteries in the cortex, chiefly at the junction of the gray and white matter. Bleeding then occurs, and, depending on the size of the vessel torn and of the rent, a small hemorrhage results, or bleeding continues and the blood infiltrates the gray matter, reaches the surface of the brain and breaks through into the leptomeninges. The explanation for the predilection of the region of the junction of the gray and white matter for the greatest injury may rest on anatomic features. Perhaps the thin meninges with the thin layer of fluid in them serve as a cushion for the surface of the brain sufficient to prevent injury to the outside, while the force as it is transmitted through the brain from a medium of lesser density (gray matter) to one of greater density (white matter) or vice versa, produces the greatest commotion at, or near, the junction.

Lacerations of the leptomeninges are another type of lesion which may depend on hemorrhage instead of on injury at the time of fracture of the cranial bones. In some instances, when these are present, the injury to the brain is only moderate as in Figure 2 *e;* but usually, there is a thick layer of blood in the leptomeninges. These lacerations of the leptomeninges are usually of the base. Perhaps the tensile strength of the thin meninges is less than the strength of the fibrous bands holding the membranes to the surface of the brain, so that when bleeding occurs from bruises of the brain, the blood, instead of spreading in the leptomeninges, ruptures them and runs into the intra-arachnoid space (subdural). This receives some support from the frequency of lacerations of the base and of the sides near the base where the leptomeninges are tightly adherent to the surface, and their infrequency at the top of the brain where they are less adherent and spread of blood in them occurs more readily.

The question may be asked why the bleeding from torn vessels at, or near, the junction of the gray and white matter is toward the outside of the brain instead of into the white matter. Again it may be stated, that bleeding follows the lines of least resistance. The cortex is softer than the white matter, owing to the preponderance of cellular tissue, so that the blood more easily spreads through this layer than through the white matter.

Another characteristic of brain bruises worthy of mention is that frequently in brains of people who die shortly after injury the bruises are superficial; whereas if life continues for one or two days, or more, larger bruises are found. This may be due to bleeding persisting for one or two days after the injury before it ceases, in this way giving the bruises a chance to enlarge.

CONCLUSIONS

1. Aside from the severe lacerations of the brain that occur at the time of injury, most bruises of the brain result from bleeding due to rupture of the pial arteries at, or near, the junction of the white and gray matter.

2. The leptomeninges with the cerebrospinal fluid in them protect the surface of the brain from injury in many instances, and the force is expended at, or near, the junction of the white and gray matter because of difference in density of these tissues.

3. Traumatic leptomeningeal hemorrhage is most frequent at the top of the brain because the thin meninges are less firmly adherent to the brain, and the spaces between the visceral layer of the arachnoid and pia are larger than at the base of the brain.

4. Lacerations of the leptomeninges of the base of the brain are caused both by trauma at the time of fracture of the cranial bones and by subsequent bleeding into them from cerebral injuries.

TECHNIC OF THE TREATMENT OF CARCINOMA OF THE BLADDER AND PROSTATE BY A COMBINATION OF SURGERY, ELECTRO-COAGULATION, RADIUM IMPLANTATION AND ROENTGEN RAY *

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Although one [1] of us (G. E. P.), in 1914, recommended, after an experience of two years, the treatment of malignant disease, particularly of the mouth, by the combination of surgery, electrothermic coagulation, roentgen rays and radium, it is true that a similar, though perhaps less efficient procedure, comprising cystotomy, electrocautery removal, application of radium *en bloc* and roentgen-ray cross-fire was actually employed by the other [2] (B. A. T.) in the same year in a patient with carcinoma of the bladder, who today is without symptoms and has never experienced any evidence of recurrence. Since the advent of the practice of using multiple small doses of radium in needle form (emanations or element), an important stride has been taken, better results achieved, and the popularity of radiotherapy greatly extended. This practice, together with the superiority of electrocoagulation over the electrocautery for the removal of the tumor mass, prompted us last year, in a paper before this section, to emphasize the empiric value of this combination of therapeutic measures in certain definite types of bladder carcinoma. It is our intention now to give in detail the precise technic employed in the management of these unfortunate cases of bladder and prostatic carcinoma.

It is of the utmost importance to appreciate fully that the treatment about to be described should be reserved for, and only applied to, certain types of carcinoma of the bladder or prostate, as defined in a

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* Read before the Section on Urology at the Seventy-Second Annual Session of the American Medical Association, Boston, June, 1921.

1. Pfahler, G. E.: Electrothermic Coagulation and Roentgen Therapy in the Treatment of Malignant Disease, Surg., Gynec. & Obst. **19**:783 (Dec.) 1914.

2. Thomas, B. A.: Technic of Operative Treatment of Bladder Tumors, Surg.. Gynec. & Obst. **21**:133-150 (Aug.) 1915.

previous paper, namely, those commonly regarded as inoperable, in which the growth is so extensive as to preclude the advisability of resection of the bladder, with or without transplantation of the ureter, or in which the vesical orifice has become involved to the extent that nothing short of total cystectomy, a procedure seldom applicable, would suffice to remove all the obviously diseased tissue, or in which the general condition of the patient will not warrant too radical or prolonged surgical intervention. Under no circumstances should this method of treatment be applied to those cases of carcinoma of such a nature and so situated that resection is possible, with or without ureteral reimplantation or transplantation, either extraperitoneally or transperitoneally; nor should it be employed on those surgical derelicts, who through personal neglect or ignorance and unscrupulous advice or procrastination, have reached the stage in the progress of disease when any aid, other than possible cystostomy for urinary deviation, avails naught. Relative to malignant disease of the prostate, the same general thought pertains; namely, radical surgical extracapsular perineal prostatectomy, if possible; otherwise, if the disease is not too extensive and no metastases have occurred, the therapeutic procedures here detailed and applied suprapubically, by cystotomy, after an interval of from two to four weeks, or after perineal exposure of the gland. The methods promise results far better than have been obtained in the past by other lines of treatment.

Realizing, first, the number of cases of vesical carcinoma not amenable to the formidable operation of partial cystectomy; secondly, the high hospital death-rate following total cystectomy associated with bilateral nephrotomy or ureteral transplantation, thirdly, the miserable existence accorded patients by a mere cystostomy for drainage; fourthly, the unsatisfactory results following either electrocoagulation or radium or roentgen ray separately, and, fifthly, the hopelessness of doing nothing at all, surgically, we have been prompted to combine four of the most effective therapeutic measures to combat malignant disease of this type.

TECHNIC

Attention to the preliminary preparation of the patient and his credentials for qualification for these operative procedures, so far as organic disease, especially kidney damage, is concerned, is just as obligatory as in cystotomy for any indication, notably prostatectomy. However, neither the operative shock nor mortality seems to be so great as in resection of the bladder or prostatectomy. Therefore, in view of the unpardonable sin of procrastination in malignancy, cystotomy, even under local anesthesia, to effect better drainage and more speedy decompression of the kidneys than can be obtained by the catheter

à demeure, may be required as a preliminary step, although it is eminently desirable, if at all possible, to complete the entire procedure, electrocoagulation and radium implantation, at one time under general, or, rarely, spinal anesthesia.

The patient is placed in the recumbent position prepared for the Trendelenburg, if desired later, with thighs abducted, knees partially flexed, feet together and strapped in position (Fig. 1). The bladder is irrigated and filled by means of a catheter with from 10 to 12 ounces of a solution of silver nitrate 1:6,000. A clamp is applied to the catheter distal to the glans penis, and a tourniquet is placed around the body of

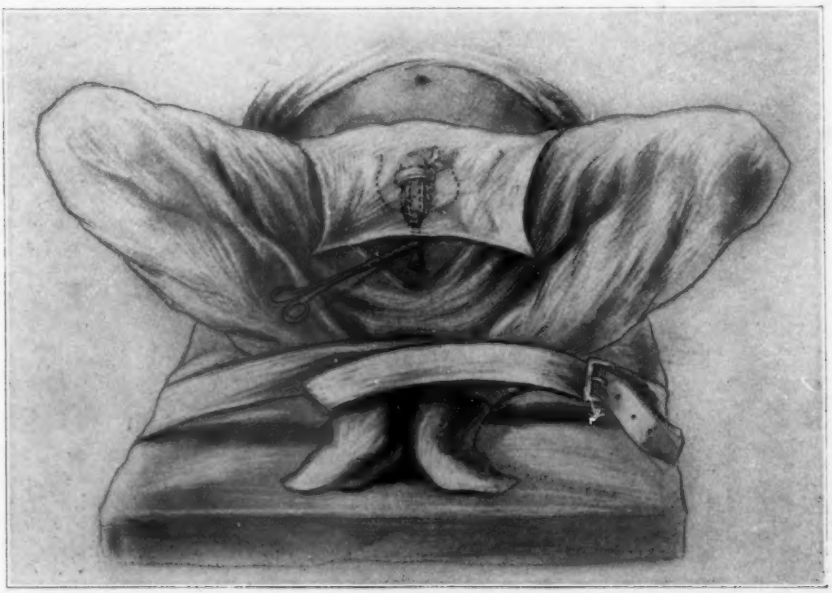

Fig. 1.—Position of patient for suprapubic cystotomy, with a sterile towel covering the genitalia, and at the same time permitting easy access to, and release of the catheter clamp, tourniquet to penis and removal of catheter after bladder is exposed and grasped.

the penis to prevent escape of the solution from the bladder. This position of the lower extremities, described by Peterkin, with the external genitalia draped with a sterile towel, readily permits the release of the catheter clamp, the escape of the solution in the bladder and the removal of the catheter, without the slightest disturbance of the patient's position, after the bladder has been exposed and fixed, just prior to incision. Also the position is desirable in the event of the introduction of a finger into the rectum to elevate the trigon or prostate.

After the usual iodin preparation of the skin, a vertical median incision is made and the bladder opened well up on the anterior wall (Fig. 2), after permitting the escape through the catheter of the silver nitrate solution from the bladder. The freshly cut edges of the wound are protected by sterile towels, and the carcinomatous mass in the bladder is exposed, using special retractors (individual are superior to

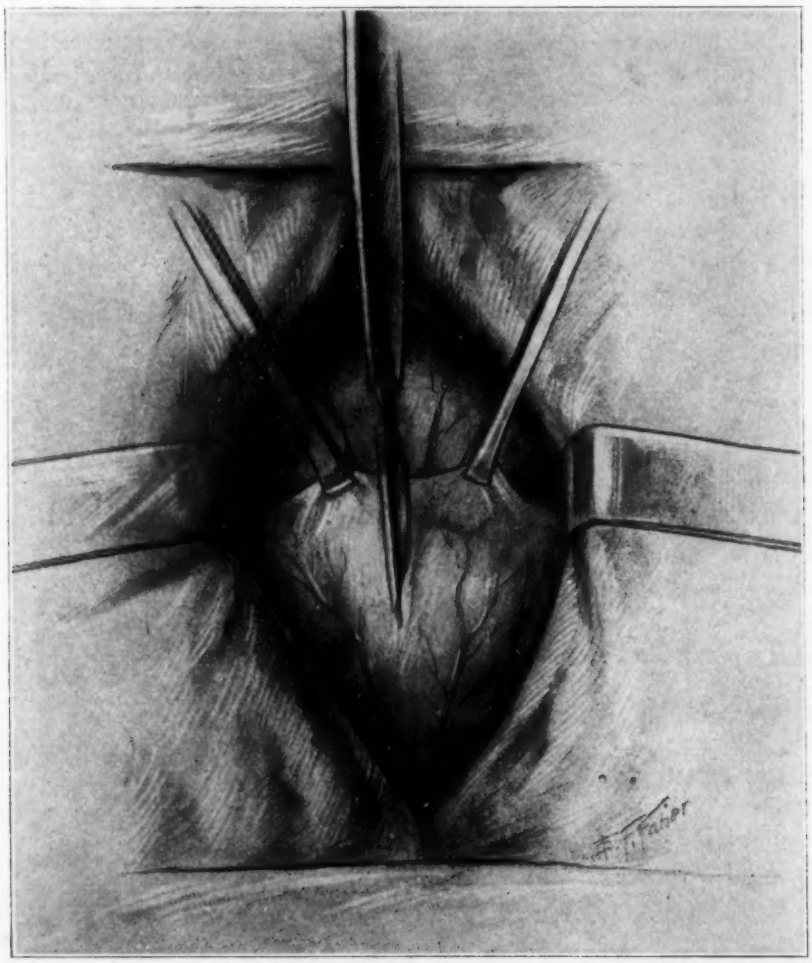

Fig. 2.—Edges of incision through skin, fat, fascia and muscle protected by sterile pads; bladder grasped by Allis' forceps and incised as high up on fundus as possible

self retaining) (Fig. 3), and the process of electrocoagulation begun. A large pad electrode (Fig. 4, *A*), measuring 6 by 8 inches is placed under the buttocks of the patient, and in direct contact with the skin.

The wire connected with this electrode must be firmly attached so that it cannot separate and make a ground with the operating table. Otherwise the current is likely to leak out to the table at some point of contact and produce a burn of the tissues in some healthy part of the body. The wire connecting this electrode should further be covered by rubber tubing (Fig. 4, *C*), so that there is no opportunity during the

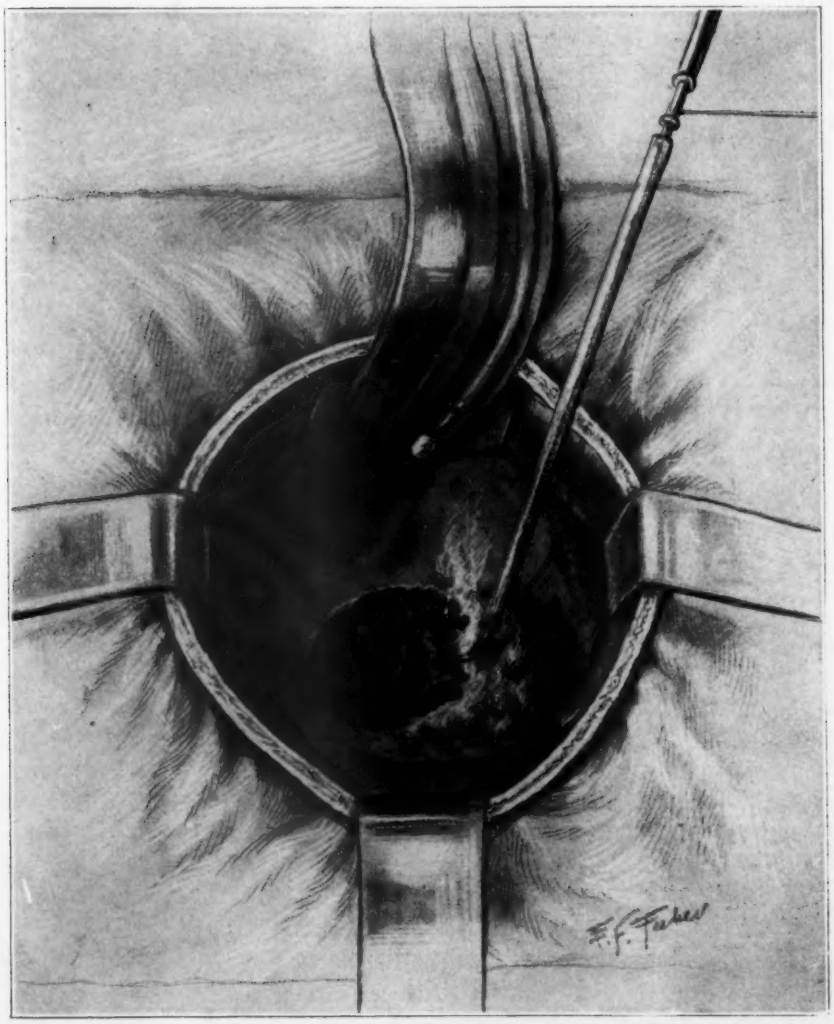

Fig. 3.—Bladder retracted, displaying carcinoma in process of destruction by electrocoagulation. The degree of heat generated in the bed of the tumor is very great and persists after treatment for a few minutes; it cannot be tolerated by the gloved palpating finger even for a few seconds, and doubtless is much more penetrating and effective than the electrocautery.

operation for the current to leap from the wire to the table. This wire, attached to the indifferent electrode or pad, is then attached to one side of the d'Arsonval instrument. The other pole of the d'Arsonval is attached to the active electrode (Fig. 4, *B*). It must be borne in mind that the d'Arsonval current is an oscillating current, and, therefore, when we speak of the poles, it must not be thought that either one of these is positive or negative, for they are alternately positive and negative, and the alternations or oscillations occur from 100,000 to a million

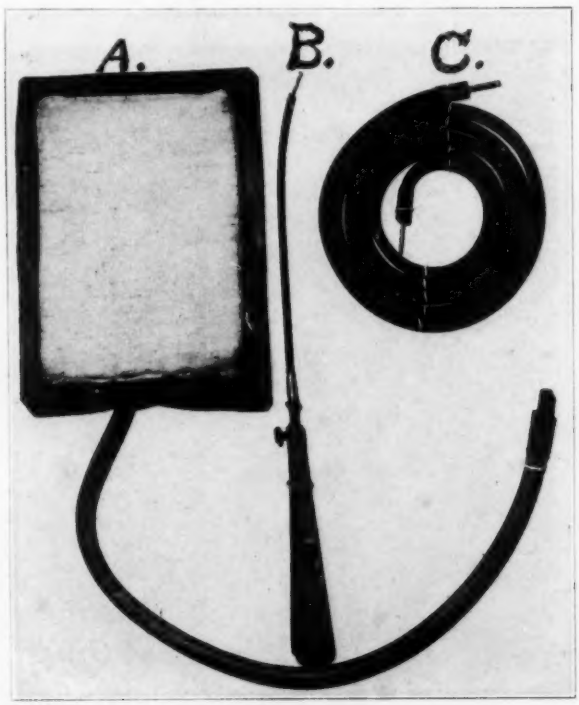

Fig. 4.—*A*, the pad which is placed under the buttocks of the patient, and the permanently attached rubber covered wire; *B*, active electrode used for destruction of the growth; *C*, type of Pfahler's rubber covered wires for carrying the d'Arsonval current. Two such wires are used.

times per second. One wire being attached to the large pad under the patient gives no local effect on the tissues in that region; but because of the great concentration of the current at the pointed or bulbous electrode which is introduced into the bladder, there is rapid destruction or coagulation of the tissues to which it is applied. Because of the danger of a sharply pointed electrode penetrating the tumor mass and starting bleeding, one of us (G. E. P.) has developed a bulbous electrode (Fig.

4, *B*) which is 9 inches long and $\frac{1}{16}$ inch in thickness, and the bulb is less than $\frac{1}{8}$ inch in thickness. This whole electrode is then covered with rubber tubing, so that when it touches the side of the abdominal wall or wound there is no local destruction, but the destructive effect occurs only at the tip of the electrode. This electrode is attached to a wooden handle, and the wooden handle in turn is attached to the wire connected with the d'Arsonval pole, or more commonly to the Oudin current pole, which is in turn connected directly to the opposite pole of the d'Arsonval instrument. All of these electrodes, needles and wires are sterilized by boiling. The spark gap and rheostat being adjusted so that a current of from 500 to 1,500 milliamperes can be used, the growth in the bladder is carefully destroyed, and each portion of the tumor is coagulated with sufficient rapidity to prevent hemorrhage, and yet slowly enough so that the steam from the cooking tissues does

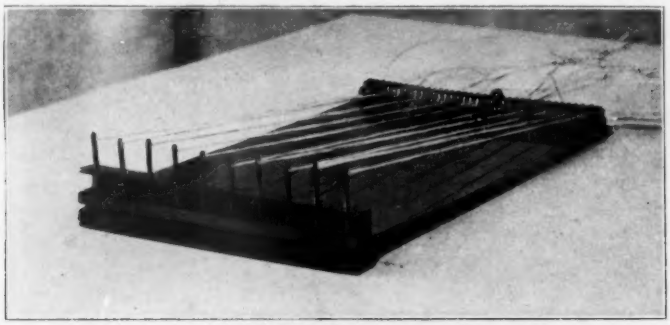

Fig. 5.—Pfahler's modification of the Bowen needle holder prepared to be dropped into a jar or pan of antiseptic solution; needles ready for insertion into the bladder. The points of the needles rest against rubber; the threads are held by a spring clamp.

not scald or macerate the wall of the bladder. The steam can be blown away by a current of cool air, but ordinarily it is practical just to work slowly enough so as to avoid this complication. The tumor tissue is destroyed until all parts are soft, and until all bleeding points have been brought under control. There will, of course, be left in the region of destruction an area of charred tissue; but there should be none of that induration which we recognize as characteristic of malignant disease. The tumor tissue after it has been destroyed may be curretted away, clipped away with curved scissors, or more generally simply wiped away with a sponge.

After all visible and palpable evidence of the tumor mass has been destroyed and removed, the bladder is irrigated with a warm solution of silver nitrate 1:4,000 to 1,000 and the incised edges of the bladder opening painted with a solution of resorcin, 5 per cent. The interior

of the bladder is then sponged as dry as possible, and the radium needles are implanted. The needles which we now use contain 10 milligrams of radium element each (Fig. 5). They are 27.5 mm. in length, 1.73 mm. in external diameter, the wall thickness of the metal being 0.4 mm. Each needle is attached to a waxed silk thread, and for this purpose we now make use of the dental floss prepared by Dunham-Reifel Company (as originally suggested to one of us [G. E. P.] by Dr. Russell H. Boggs). This is sterilized as it is prepared. It is again sterilized in chemical solutions before being used. The radium needles and the threads can be sterilized either by means of pure phenol fol-

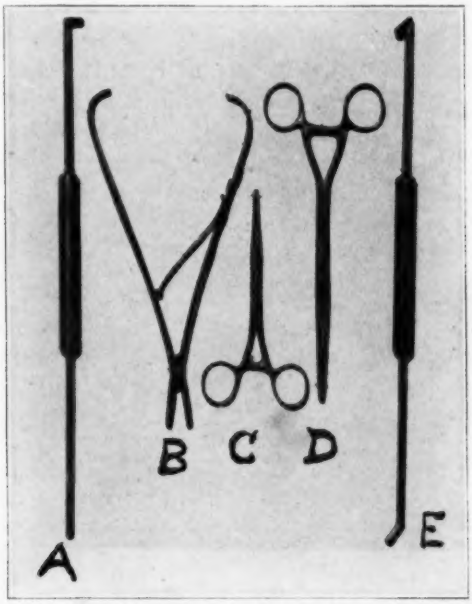

Fig. 6.—*A*, radium needle holder with arrangement for straight insertion at one end and insertion at right angles at the other; *B*, leaded jaw forceps for grasping and inserting radium needles; *C*, special grooved hemostatic forceps for forcing the needles to a deeper point; *D*, longer forceps for the same purpose, and *E*, needle holder for inserting needles at an angle of 45 degrees.

lowed by an immersion in alcohol, or in 10 per cent. liquor formaldehydi or in 95 per cent. alcohol. These needles are introduced by carriers (Fig. 6) into the base of the tumor, approximately from 1 to 2 cm. apart, and left in place from eight to eighteen hours, depending on the probable degree of malignancy and the extent of the disease (Fig. 7). The smaller the area of disease and the closer the needles, the shorter the period of time the needles are allowed to remain. From six to fifteen needles are used depending upon the size of the base of the

tumor. Up to the present time we have observed no vesicorectal fistula, and we have not observed any necrosis of normal tissue as a result of the introduction of the needles. Electrocoagulation is, of course, followed by sloughing of the destroyed tissue and this process will require approximately three or four weeks. The sloughing tissues are macer-

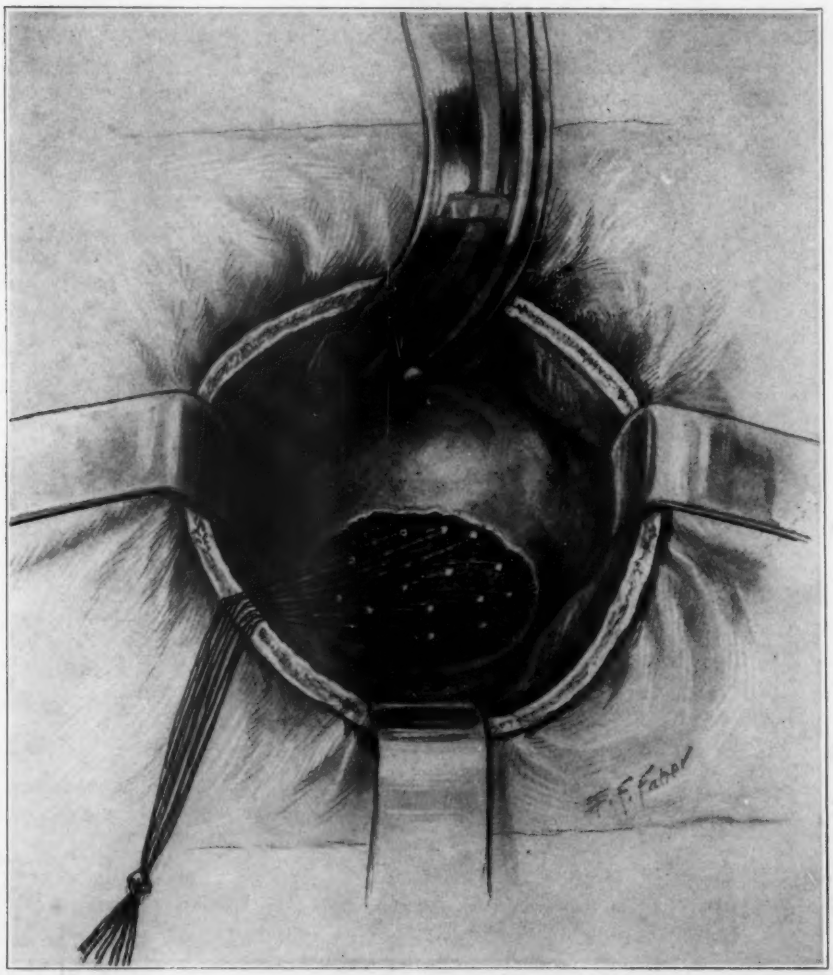

Fig. 7.—Disposition and arrangement of radium needles in the bed of the electrocoagulated area, following destruction and removal of the tumor.

ated by and carried out with the urine, either through suprapubic drainage or through the urethra.

A large sized, properly fenestrated rubber drainage tube, 2 to 2½ cm. in diameter, is introduced into the bladder, care being exercised not

to allow the end to impinge on the vesical trigon (Fig. 8), and retained at the upper angle of the bladder incision by closure of the wound below with continuous chromic gut suture (Fig. 9). The strand of threads attached to the radium needles is either passed out through the drainage tube or along the inferior aspect of the tube externally. A small fenestrated rubber tube passing into Retzius' space, for perivesical drainage, in case of bladder leakage, is secured to the lower angle of the skin incision. The large tube is then rotated downward and

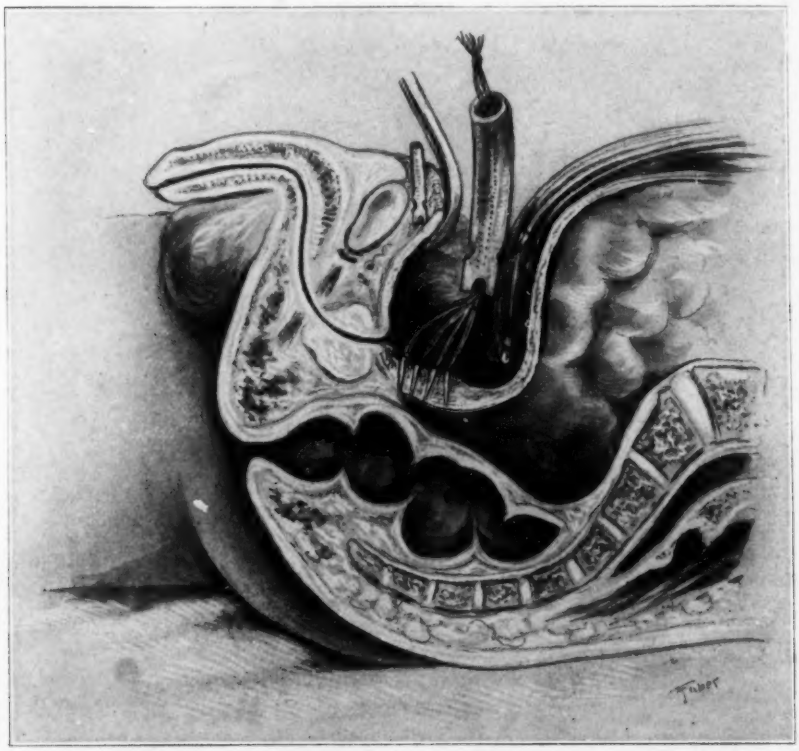

Fig. 8.—Sagittal section showing position of radium needles and conduction of their silk thread guides through properly placed drainage tube.

secured by suture of silkworm gut to the skin on either side of the incision just above the small prevesical drain (Fig. 10). The recti muscles are drawn together by one or two sutures of plain gut, and the fascia closed to the level of the tubes by a continuous suture of chromic gut. The skin is closed by interrupted sutures of silkworm gut and the radium needle threads secured for the time desired, if passed through the lumen of the drainage tube, by an L-shaped glass drain connector (Fig. 11). At the end of the first week after operation,

the drainage tube and all sutures are removed, and a special suprapubic drainage ambulatory apparatus is fitted to the patient (Fig. 12). This device, as a rule, suffices to keep him dry, either in bed or out, and thereby saves much gauze and cotton otherwise necessary for the absorption of urinary leakage.

Should the carcinoma be one involving the prostate gland, treatment, as a rule, should be applied both suprapubically and perineally. The

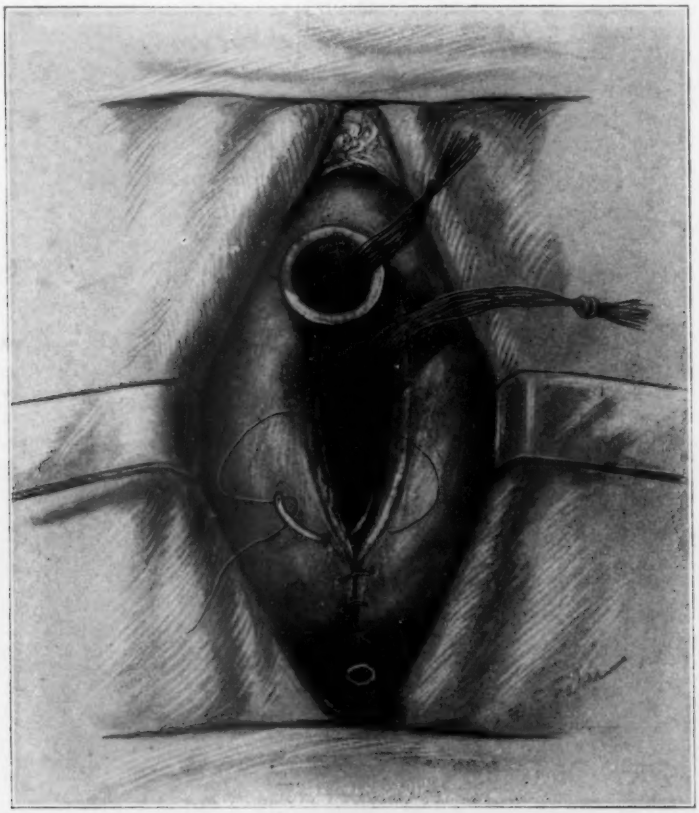

Fig. 9.—Closure of bladder showing proper placement of vesical and perineal drainage tubes. The radium needle threads may be conducted from the bladder either through the large vesical drainage tube or beside it above the continuous suture.

character of the carcinomatous growth, tending either to infiltrate or project into the bladder, or to be confined mainly to the posterior and lateral lobes of the prostate, will determine whether the primary attack should be made above or below. This decision will be aided materially by the findings of rectal palpation and cystoscopy.

The suprapubic technic differs in no essential from that employed when the carcinoma is confined to the bladder, excepting that when there is little protrusion of the growth into the bladder, destruction of the mass by electrocoagulation will not be necessary and the radium needles can be inserted immediately into the growth about a centimeter equidistant, as pointed out by Herbst[3] (Figs. 13 and 14), or as described above.

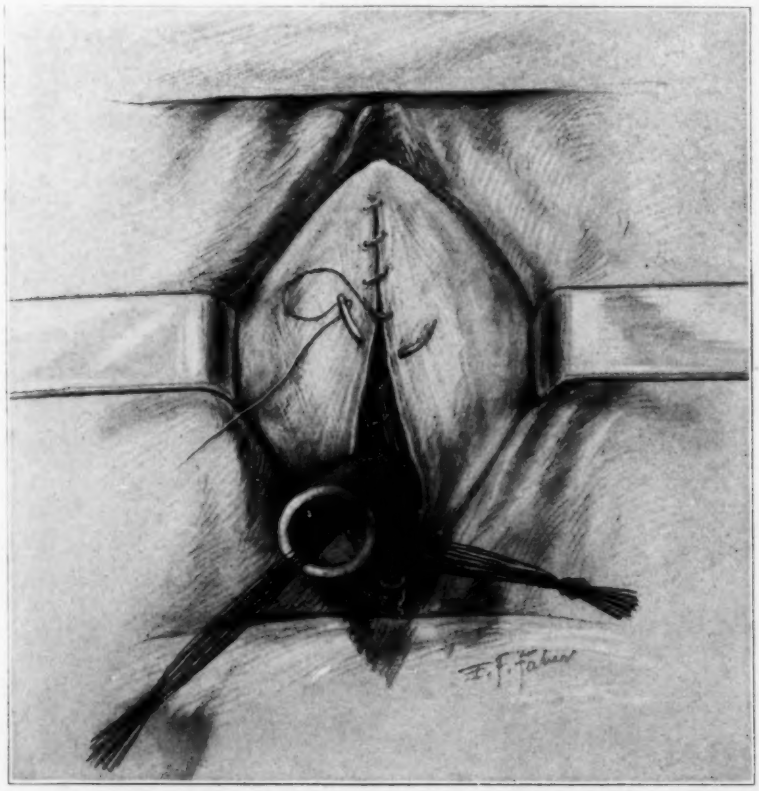

Fig. 10.—Bladder has been rotated downward by drainage tube, subsequently to be fixed by suture at lower angle through both sides of skin incision. Apposition of recti muscles by one or more interrupted sutures, also closure of fascia above tube, may be noted.

The perineal exposure of the prostate is best effected in the manner employed for prostatectomy, with the patient placed on the Halstead perineal board attached to any operating table (Fig. 15). The car-

3. Herbst, R. H.: Cancer of the Prostate; Combined Surgical and Radium Method of Treatment, J. A. M. A. **72**:1610 (May 3) 1919.

cinomatous gland is approached by the usual dissection and when exposed may be presented advantageously by two heavy traction sutures introduced in the tissues of the basal angles (Fig. 16), or by the insertion of the prostatic tractor (Fig. 17). In many cases, no traction will be required for sufficient exposure of the gland for the introduction of the radium needles. Just as in the case of the bladder, these

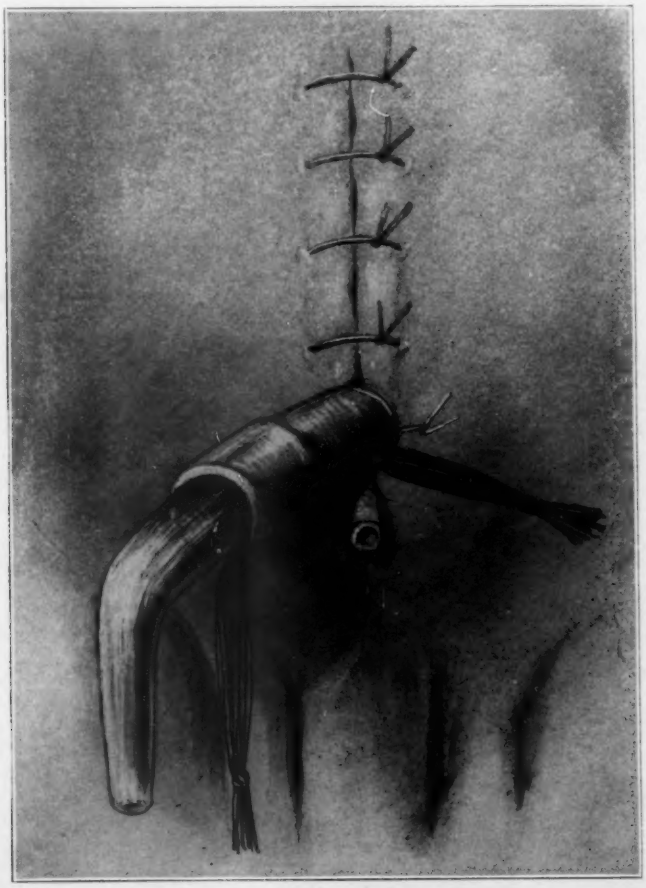

Fig. 11.—Suture of skin showing proper position of drainage tubes and disposition of threads attached to radium needles; showing manner in which threads are secured by glass drain connector if brought out through rubber tube.

needles are inserted about a centimeter apart, care being taken to avoid the urethra, at the same time assuring complete radiation of the posterior lobe, that part of the gland most commonly primarily involved and lying directly posterior to the urethra. The strand of threads attached to the needles is brought out one of the angles of the skin

incision, either alone or in conjunction with a drainage tube passed through the prostatic urethra into the bladder, in case the urethra has been opened (Fig. 18). The perineal drainage of the bladder, or by catheter through the urethra, may be necessary for a few days to obviate urinary obstruction in the prostatic urethra due to swelling of the prostate, incident to the action and reaction of radium.

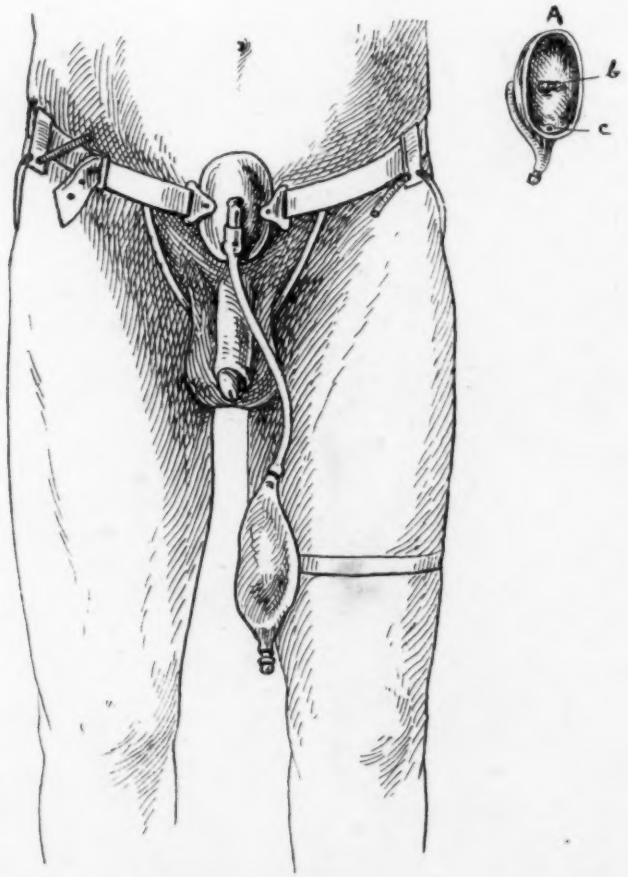

Fig. 12—Suprapubic drainage apparatus fitted to patient on removal of intravesical rubber tube drain; *b*, detachable metal tip removed in a day or two, for the temporary attachment of decreasing sizes of rubber drainage tubes; *c*, opening for escape of urinary overflow into cup.

Intensive roentgen-ray cross-fire may be of advantage and should precede operative intervention, thereby destroying outlying carcinomatous foci in the lymphatics, limiting the spread of the disease temporarily and probably preventing certain metastases that might otherwise occur. In any event, whether employed before operation or not,

as soon after surgical intervention as the condition of the patient will permit, electrocoagulation, radium implantation and roentgen-ray treatment as here described should be instituted.

Anteoperative roentgen-ray treatment in all forms of malignant diseases is probably more important than postoperative treatment. It has been recommended for a considerable time by one of us (G. E. P.). (It

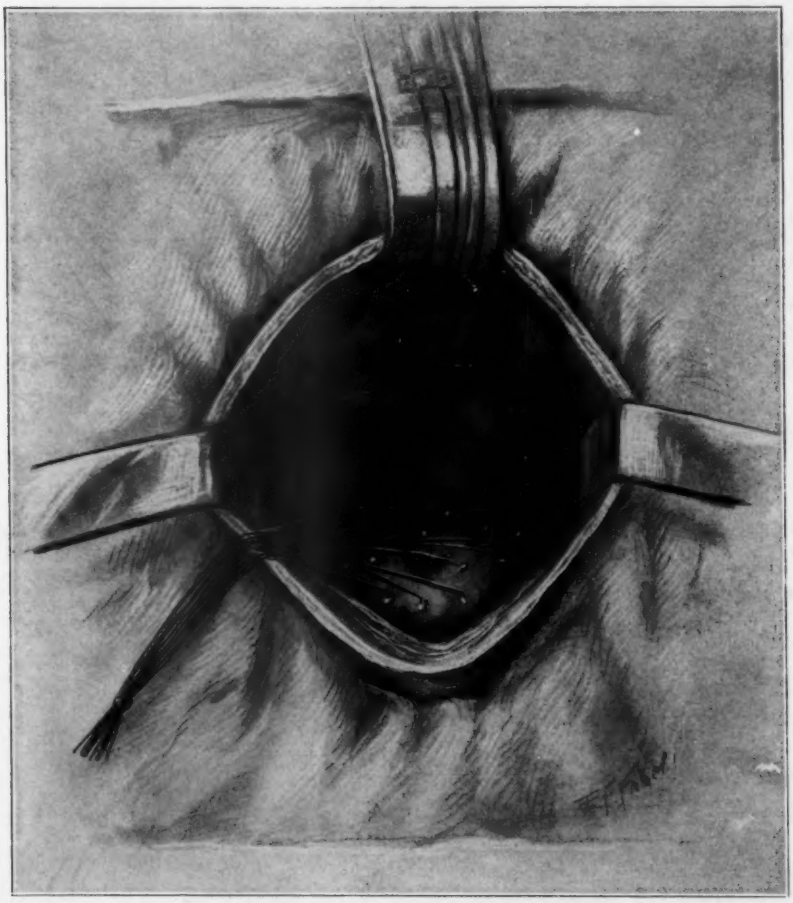

Fig. 13.—Arrangement of radium needles in vesical projection of carcinomatous prostate.

is especially important in treatment of malignant disease of the bladder because of the great likelihood of metastases having developed before the patient comes under active treatment.) This anteoperative roentgen-ray treatment will consume a period of about two weeks. It is not intended that it should be used with the idea of circumventing operation,

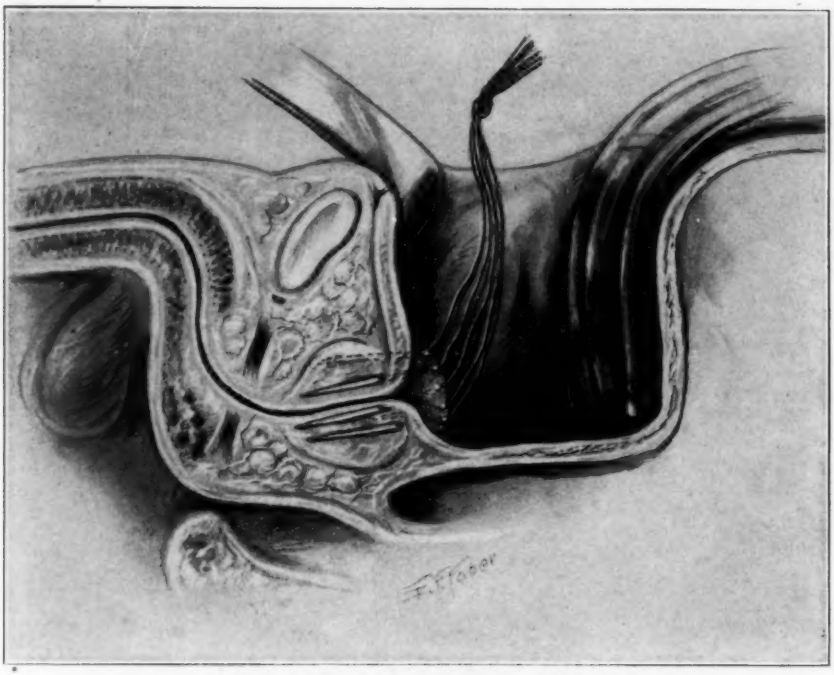

Fig. 14.—Sagittal section showing disposition of needles in prostate.

Fig. 15.—Position of patient on Halstead board and incision employed for perineal exposure of prostate.

or with the idea of waiting to see results, but entirely with the object of devitalizing carcinomatous tissue so that there is less likelihood of transplantation or recurrence following operation. This roentgen-ray treatment should cover the entire pelvic area and extend as far up along the line of lymphatics as is probable that the disease has traveled. The plan of treatment will be modified somewhat according to the amount of disease and its duration in each individual case; but in a general way, the anteoperative treatment in the average case will consist in dividing the area between the umbilicus and symphysis pubis into two areas by a

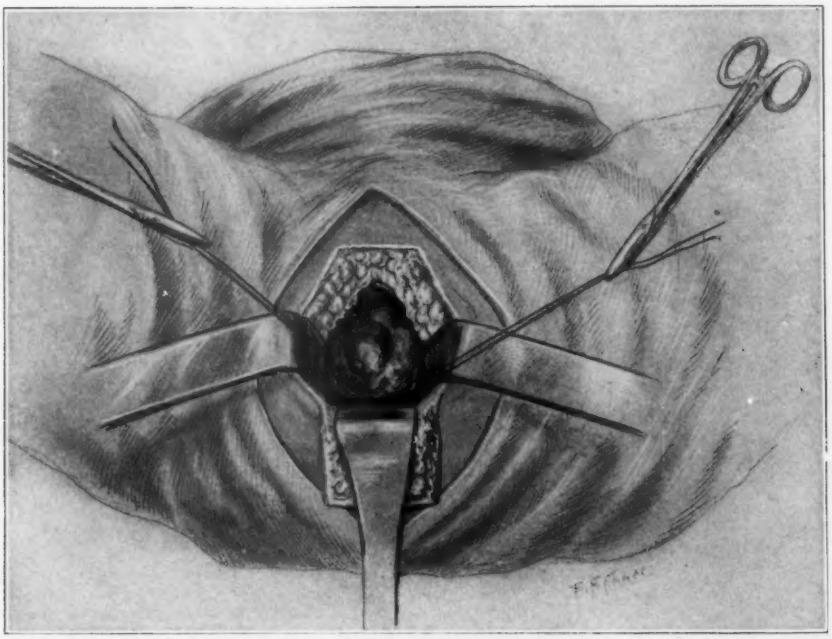

Fig. 16.—Exposure of carcinomatous prostate gland facilitated by traction sutures of heavy silk.

vertical line. The outer border of each area is marked by a line extending vertically through the anterior superior iliac spine. Posteriorly, it is best to divide the pelvic area into two regions by a line extending through the middle of the sacrum. The rays are then directed through the anterior fields so that in their distribution they will cover the proximal and the opposite side of the deep portion of the pelvis. Posteriorly, the rays are directed through the great sacrosciatic notch so that they will cross at about the center of the pelvis. Through each of these areas all the rays that the skin will tolerate must be given. In other

words, a full skin dose, which is just short of an erythema dose, should be given through each of these areas. For this purpose, one must use the technic and the amount of treatment which has been found to produce a skin dose with the particular instrument in use. For this purpose, we use with our instruments 6 mm. of filter, at a focal skin distance of 30 cm., from 25 to 30 minutes exposure with a 9 inch parallel spark gap, and 5 milliamperes of current. As postoperative treatment, at least two such full doses should be given through each area, beginning about two weeks after the radium application, and repeated again about three or four weeks later.

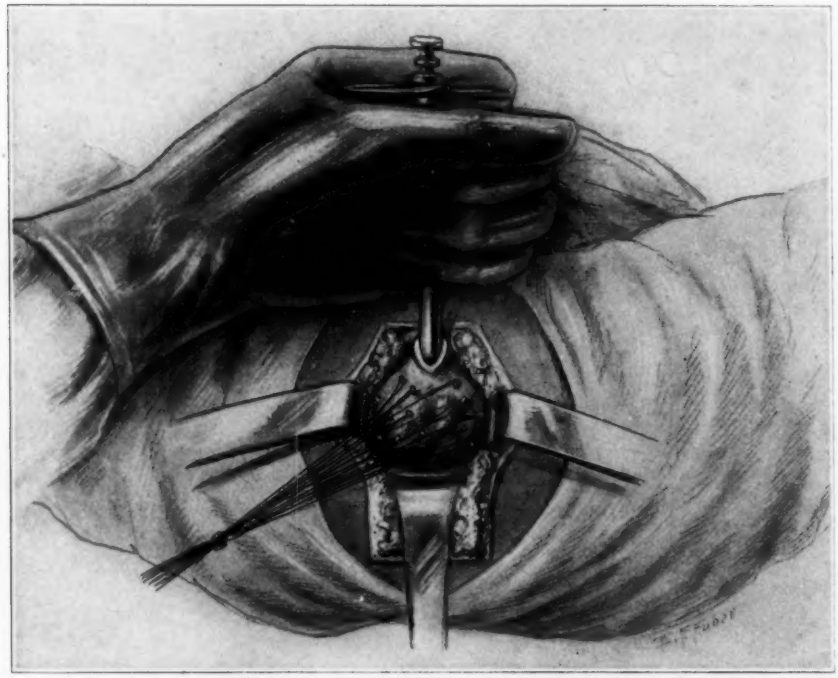

Fig. 17.—Display of gland, aided by prostatic tractor; radium needles inserted into carcinomatous tissue, avoiding urethra.

RESULTS OF TREATMENT

Employing this combination, or quartet, of therapeutic measures, twenty-six patients have been treated. It is true that originally, in a few cases, our methods, with the present technic, were comparatively crude in some respects. Until three years ago, when the small needles came into use, we were obliged to plant the radium *en masse* into the growth or its bed; also, the electrocoagulation of the growth was not

so intensively and thoroughly done; indeed, in some instances, the tumor was destroyed or removed by the electrocautery, prior to the implantation of radium. Nevertheless, it is a remarkable fact that in our series of cases, although some patients have not been relieved of their symptoms, or their symptoms have returned after a period of improvement or actual freedom, only two are known to be dead, and one has been untraceable, a result we dare say that could not have been paralleled by any other form of treatment. The majority of these patients have been treated and observed only during the last three years, therefore, we are not justified in drawing conclusions, nor is it

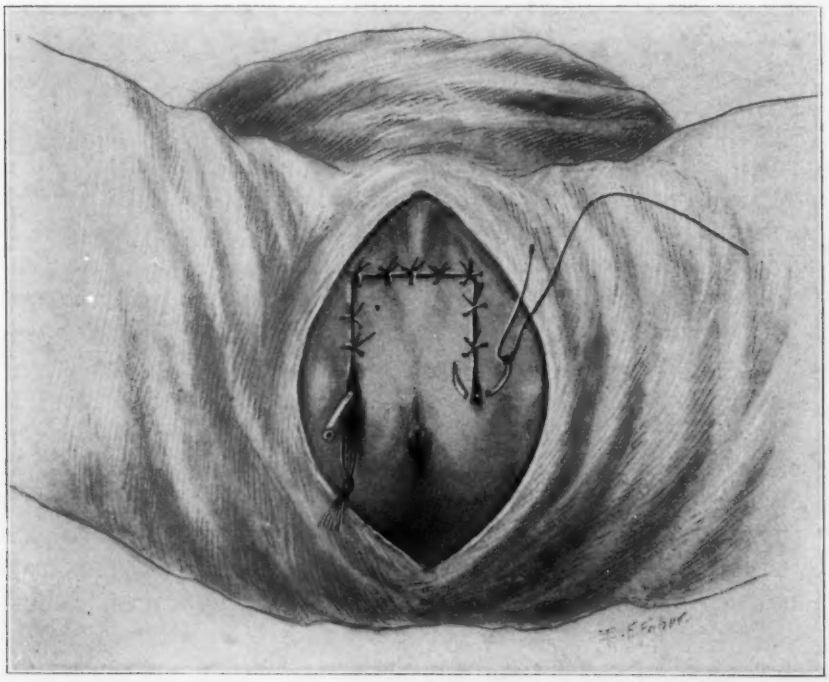

Fig. 18.—Closure of perineal wound and arrangement of radium needle threads with respect to drainage tube.

our intention to make any particular claims as to end-results. We desire simply to describe the technic evolved from experience and at present employed in this surgically unwelcome and disheartening type of formerly inoperable bladder and prostatic carcinoma, and to say that it is our conviction that the treatment here described and practiced offers more in the way of prolongation of life, if not cure in a few rare instances, than any other method of treatment heretofore employed in this particular deplorable type of malignant disease.

A DETAILED BACTERIOLOGIC STUDY OF A CASE OF GAS GANGRENE FOLLOWING A COMPOUND FRACTURE

STUDIES ON PATHOGENIC ANAEROBES III*

CLINICAL OBSERVATIONS BY
EDNA L. BARNEY, M.D.

BACTERIOLOGIC STUDIES BY
HILDA HEMPL HELLER, PH.D.
SAN FRANCISCO

CLINICAL OBSERVATIONS

A summary of prewar cases of gas gangrene has shown that this type of infection occurs far more often with compound fractures than with any other type or condition of wound, and that the occurrence of gas gangrene in civil life is extremely uncommon, only 175 cases having been reported up to 1915. Data on this subject since the war show that the percentage of gas gangrene cases in war wounds was moderate, ranging in different localities from 1 to 3.5 per cent.

In the 175 cases collected from the literature up to 1915 by Simonds,[1] the relative number of several types of wounds was as follows: compound fractures, 61; lacerated wounds, 28; operation wounds, 11; gunshot wounds, 10, and hypodermic needle puncture, 9. Thus nearly as many cases of gas gangrene developed in hypodermic needle punctures and slightly more in operation wounds than in gunshot wounds. Gas gangrene was twice as frequent in lacerated wounds and six times more frequent in compound fracture cases than in gunshot wounds. This refutes the impression gained from war reports that gas gangrene was peculiarly incidental to gunshot wounds. Furthermore, the relatively high frequency of gas gangrene in compound fracture wounds as compared to some other types of wounds, which are equally liable to contamination by foreign substances, argues for a different accessory agent to the growth of gas gangrene organisms than is supplied by the nidus theory.

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* From the Department of Surgery and the George Williams Hooper Foundation for Medical Research, University of California Medical School.

1. Simonds, J. P.: Studies in B. Welchii with Special Reference to Classification and Its Relation to Diarrhoea, Rockefeller Institute for Medical Research, Monograph 5, 1915.

In the experiments of Bullock and Cramer,[2] particles of wood, cloth, paper and other foreign substances, after being soaked in a suspension of *B. welchii,* were introduced beneath the skin of mice with negative results. *B. welchii* was also introduced into hematomas with negative results. Bullock and Cramer found, however, that the presence of certain calcium salts aids in the production of gas gangrene. Doses of 2½ mg. of calcium chlorid injected with a suspension of *B. welchii* or of *Vibrion septique* never failed to produce gas gangrene in the experimental animals. Calcium nitrate and calcium acetate have the same effect. The conclusion of Bullock and Cramer was that calcium salts produce at the site of injection a local change in the tissues which lessens their defensive mechanism. Therefore, does it not seem probable that calcium salts, liberated by the disintegration of devitalized bone substance in compound fractures, may supply, to a large extent, the factor that lessens the resistance of the tissues to gas gangrene anaerobes?

Whether a fracture is compounded from within outward by a bone fragment or from without inward by a foreign body, there is in either case ample opportunity for bacterial invasion. But in compound fractures, not only the severe traumatization of the bone substance itself, but the usual traumatizing effect of the bone fragments on soft tissue cause far greater devitalization than would result in a corresponding injury to soft tissue without fracture. The increased devitalization burdens both the injured and adjacent tissues with a greater metabolism complex and no doubt a lowered cell resistance. This increased devitalization, which includes both bone and soft tissue, is probably an important accessory cause for the increased susceptibility of compound fracture over other wounds for the development of gas gangrene.

REPORT OF CASE

History.—M. R., aged 8 years, schoolgirl, American, entered the surgical clinic of the University of California Medical School, Oct. 2, 1919. On the evening of October 1, the patient fell from a bench, 4 feet above the ground, injuring her arm. The ground was covered with dry grass and showed nothing to suggest any particular contamination. The child's home was close by, and next to a barnyard. There were several goats in the vicinity.

Immediately after the accident, the child, with the injured arm wrapped in a towel, was taken to an emergency hospital, where at 8 p. m., the fracture was reduced and the arm was splinted.

Examination.—When the patient entered the surgical clinic the next morning, the entire forearm was moderately swollen, but not more so than would be expected from a fracture of both the ulna and the radius. Over the middle third of the ulna on the volar surface was an open wound, 1.5 cm. in length.

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2. Bullock, W. E., and Cramer, W.: On a New Factor in the Mechanism of Bacterial Infection, Proc. Royal Soc., Series B **90**:513, 1919.

Inquiry elicited the fact that before reduction at the emergency hospital, the lower fragment of the ulna was protruding through the wound. At the time of examination at the surgical clinic, fourteen hours after injury, no symptoms nor signs of gas gangrene were noted. But the following morning, October 3, when the child returned to the clinic, the forearm was gangrenous, with circulation stopped just below the elbow. The entire arm was greatly distended, and edema had extended into the shoulder muscles. From gangrenous blebs on the wrist, when punctured, oozed a bloody serum and bubbles of gas. Gas bubbles also issued from the wound.

Operation and Result.—The arm was amputated, guillotine method, just below the level of the insertion of the deltoid muscle. The amputation was well above the lowest line of the circulation. Smears made at this time from the wound in the forearm showed the presence of *B. welchii.* No tetanus organisms were found; but 1,500 units of tetanus antitoxin was administered subcutaneously.

On the morning following the operation, 20 c.c. of *B. welchii* antitoxin, which was the only available antiserum related to gas gangrene, was given intravenously. We were able, fortunately, to obtain *B. welchii* antitoxin through the courtesy of Dr. K. F. Meyer of the Hooper Foundation. On the second day following the operation, 15 c.c. of this antitoxin was given subcutaneously, about 50 antitoxin units in all. The child was apparently very toxic. A marked tachycardia developed, together with restlessness, delirium, stupor and cyanosis. The wound was treated with surgical solution of chlorinated soda (Carrel-Dakin solution). It was dark in color, with patches of crusts covering sloughs. The patient remained in restless delirium until the eighth day after operation; the pulse rate increased to 160, and the temperature to 39.2 C., rectally. There was a blowing systolic murmur heard over the precordium; the liver edge was 3 cm. below the costal margin; but the splenic margin was not palpable. There were also, on the eighth day, definite signs of serum sickness with edema of the eyelids and lips and herpes on the lips. There was also vomiting and diarrhea. The wound had not begun to granulate but was still the color of old meat. The Carrel-Dakin solution was discontinued, and a mild solution consisting of salt solution and hydrogen peroxid was substituted.

On the following day, the ninth day after operation, the pulse rate began to drop; the child became rational; the sloughs began to disappear, and the child advanced steadily to complete recovery. She was dismissed from the hospital on the twentieth day after operation.

PATHOLOGIC ANATOMIC NOTES

The examination of the arm amputated was undertaken three hours after the operation. The odor of the arm was strong, rank and penetrating, but not putrid. It resembled that of butyric acid; but there was also a rank, peculiar odor similar to that of blackleg muscle in cattle. The arm was rigid as it had been before amputation. The tissues were about as resistant to pressure as a very hard rubber ball, the moist skin of the forearm showing considerable stretching and tension. On the wrist and on the palm of the hand were several long bullae filled with a serous colorless liquid. The hand and fingers were very edematous and had a white transparent appearance. Crepitus was present in the hand, wrist and forearm. On the flexor surface,

midway between the wrist and elbow, was a small wound about ¾ by ¼ inch in area. This had probably been caused by perforation by the fractured ulna. The forearm showed blue marks and abundant indications of contusions. There was no bronzing of the skin unless a certain dark discoloration of that on the wrist may be so designated. The elbow was greatly swollen as was the upper arm, but above the elbow crepitus was absent.

The cut end of the arm showed a bubbling of gas at the site of the principal blood vessels. A large amount of blood escaped from the arm before it was examined, probably on account of the gas pressure.

An incision made along the flexor surface revealed a varying amount of gas in the different portions of the arm. Most striking was a gradual spreading of the skin of the wrist, till it lay open for a space of more than an inch. Gas was released from solution where it had been confined by the pressure exerted by the integument, and large bubbles appeared in the connective tissue and among the muscles, distending the tissue greatly. The muscles in this region were slightly dry and somewhat hemorrhagic. They were not brick colored or yellowish nor had they in any great measure lost their elasticity. Section of the palm allowed considerable bubbling to take place; but it was apparent that most of the swelling of the hand was due to a white edema that retained its gelatinous consistency on section. The muscles of this region were normal or slightly pale in color; all the tissues were moist and elastic, and there was no turbid exudate except a little fluid that contained a few red cells. The large muscles of the upper portion of the forearm were moist, edematous and contained a considerable amount of gas. This bubbled forth for some time after section without the application of any pressure. Its odor was rather rank and sweetish, the butyric acid element not being marked, and a true proteolytic odor not being noticeable. All the muscles were hemorrhagic, most of them uniformly so. The fracture of the ulna had occurred in the middle of the shaft; that of the radius was comminuted and in the upper third of the shaft. Examination of the broken ends showed that the arm had been shortened a quarter of an inch, perhaps partly by the pressure of the gas. On the muscle next to the fractured end of the ulna was a yellowish discoloration thought to be due to bacterial action. Bacteria were, however, not found to be especially abundant in this region. The muscles of the forearm surrounding the fracture were somewhat darker, and the region immediately about the fracture of the radius was marked by the presence of much gas and areas of black hemorrhagic infiltration of the muscles. Extending toward the elbow, several of the muscles showed irregular, small and large black hemorrhages. On the flexor surface of the elbow was a small lacerated blood vessel

Form No. 59—10m-5,'19

UNIVERSITY OF CALIFORNIA HOSPITALS GRAPHIC CHART

UNIVERSITY OF CALIFORNIA HOSPITAL — HAHNEMANN HOSPITAL

October 1919

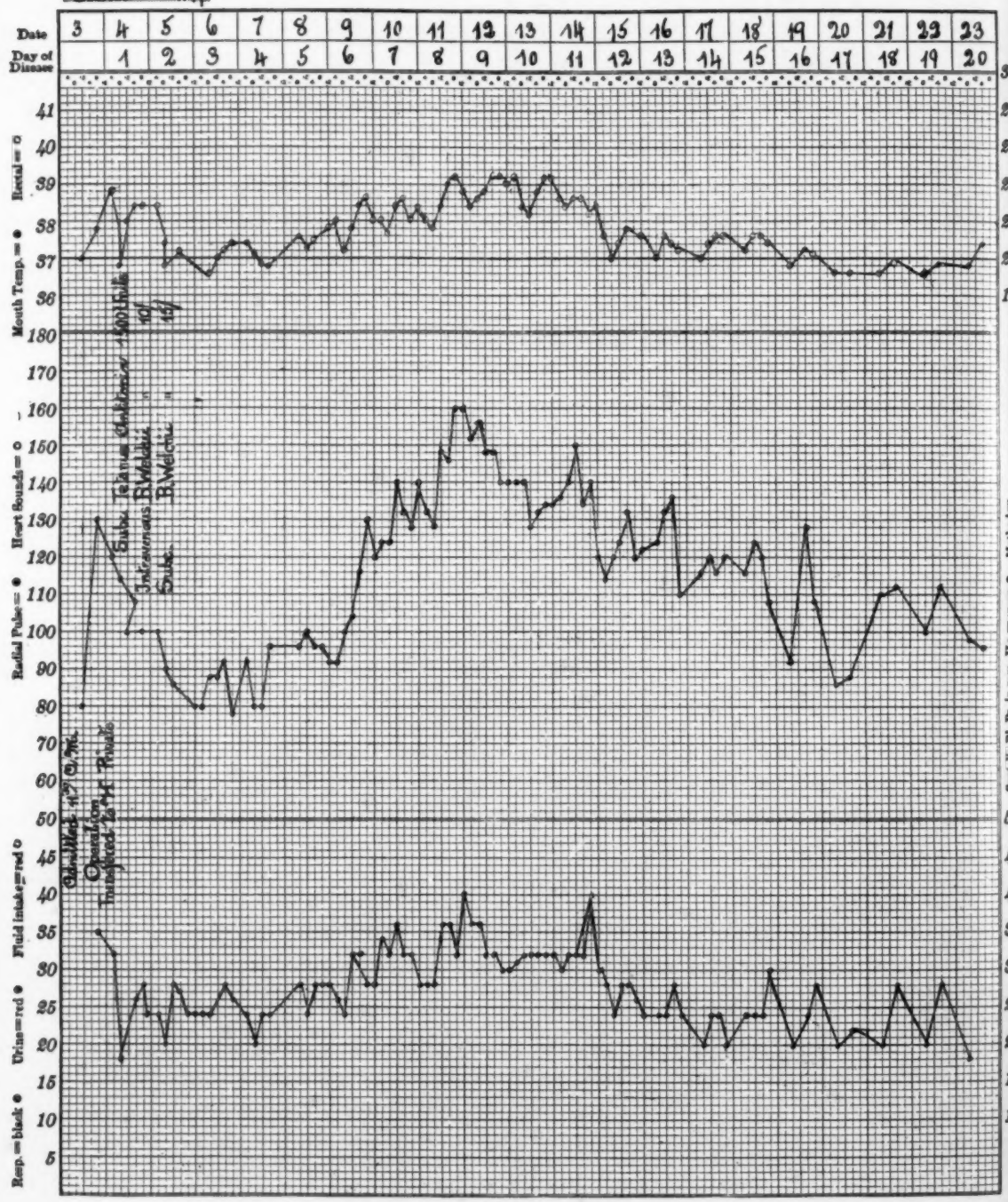

Chart of remarkable tachycardia in a case of gas gangrene.

containing a clot. The fascia of this area and the muscles below it were blackish red and contained gas. Aside from the gas and color changes, the muscles appeared normal. Nowhere in the forearm was there any pus or exudate. The muscles of the upper arm were but little affected. The fat-containing fascia of this region was, however, markedly gelatinous and contained no gas. The edematous fascia retained its consistency long after section, only a little blood-stained exudate leaking forth.

Twenty-four hours later the arm had lost its rigidity almost entirely, though it had been kept on the ice in the meantime. It is not unlikely that this rapid loss of rigidity was partly due to the escape of the gas and partly to the effect of the bacterial action on the tissues. The muscles were distinctly flabby but not putrid. The connective tissue of the upper arm had lost its gelatinous consistency. A week later, it was found that the area of blackish discoloration was spreading toward the line of amputation, especially near the bone. The arm kept for some time in the refrigerator developed no signs of normal decomposition and the odor remained as before.

MICROSCOPIC AND CULTURAL FINDINGS

At the site of the small perforating wound over the fracture of the ulna were found thick, short, gram-positive, square-ended rods, and in a minority somewhat longer and more slender round-ended rods, not to be easily distinguished from the shorter ones when stained with a thick gentian violet gram stain. A meat medium culture from this region gave an extremely vigorous growth of typical *B. welchii.* In this culture, contaminations were noticeable only after the elimination of *B. welchii* by heat.

A smear from the muscles of the wrist, the region where there was most gas, showed both types of organisms, the heavy rod and the slender rod. A culture gave predominantly *B. welchii.* When this organism was killed, various others were found to be present.

Smears from the palm of the hand showed a clear staining gram-negative rod with rounded ends, and occasional terminal oval spore-bearers. (The thin methyl violet gram stain [3] of the home laboratory was used for this and all the following stains.) A culture on meat medium gave, in twenty hours, gas and a gram-negative rod. This organism produced only a faint pink coloration of the meat particles. The culture seemed to die on exposure to the air, as subcultures showed only a small saprophyte that produced no gas. There was no hint of the presence of *B. welchii.*

3. Heller, H. H.: The Etiology of Acute Gangrenous Infections of Animals, J. Infec. Dis. **27**:385 (Nov.) 1920.

Smears from the site of the fracture of the ulna and the muscles above it gave little or no indication of the presence of *B. welchii*. They showed everywhere gram-negative rods, single and in pairs. These were most abundant at the site of the fracture and in the deep red hemorrhagic muscle. The organisms in the muscles in general were vegetative only; those at the site of the fracture were sporulating. The spores were large, oval, usually terminal, with thin walls. They are best described as racket shaped. No bilaterally asymmetrically placed spores were seen. Some bacilli from this region were irregular in their staining, reminding one of the granulose forms of *Vibrion septique*. The edematous fascia of the upper arm contained a very few organisms, some of them sporulating. These were found close to the line of amputation. Cultures taken above the fracture of the ulna gave no Welch bacilli whatever. They contained an organism making a large woolly colony of loose structure with a halo of hairlike radiations. This organism was, so far as it is possible to state, the sporulating one seen on the smears. It proved to be a variety of *Vibrion septique*. A remarkable feature was its greater size in human tissue than in guinea-pig tissue. The eye trained to seeing anaerobes in guinea-pig tissue would find the large racket shaped rods in human tissue more like those of *B. oedematiens* than like *Vibrion septique*. A guinea-pig inoculated in the thigh with 0.5 c.c. of a twenty-four hour culture died in sixteen hours and showed moderate hemorrhagic infiltration of the muscles, little edema, a little gas in the inguinal region, marked injection of the peritoneum, injection of the intestines and of the suprarenals, enlargement of the suprarenals and an invasion of the lungs as shown by congestion and hyperemia. Such lung invasion is rather unusual in the case of *Vibrion septique* strains and is apparently constant in the case of this strain in the guinea-pig body. The lung and liver and peritoneum showed long gram-positive filaments, which are very reluctant to form spores even after forty-eight hours at room temperature; the muscle at the site of inoculation showed forms in all stages of development from purely vegetative, through granulose, swollen forms to sporulating forms. This organism was found also in the wrist and was apparently present in the hand, though cultures failed to show its presence.[4]

4. The technic used in the isolation of these strains was simple. Dilution shakes were made in deep peptone liver agar of samples from various portions of the arm. Peptone liver agar is an excellent medium because an exceedingly wide range of anaerobes will grow on it. These shakes were searched carefully and persistently for unusual colony types, and such, when found, were isolated on liver agar and then planted into meat. From the meat, all different types were inoculated into the thigh muscles of guinea-pigs. Details as to the operation of my isolation technic will be found under the title "Principles Concerning the Isolation of Anaerobes," J. Bacteriol. **5**:445 (Sept.) 1921.

There was also, wherever *Vibrion septique* was encountered, an unidentified gram-negative rod that made small dense colonies with short radiations and that belonged to the nonproteolytic group of anaerobic bacteria This organism appeared to be wholly nonpathogenic for the guinea-pig. We shall call it *Bacillus S.*

From the elbow was isolated a third invader that is of interest. It produces lesions much like those caused by certain oedematiens group strains, but culturally it cannot be included in such a group. It possesses distinct though mild proteolytic powers, and in many minor ways differs in its habits from oedematiens group of organisms. This bacillus has marked toxic properties for the guinea-pig and only moderate invasive ones. It usually becomes septicemic in that animal, a fact of interest, because of its invasion in the human case. Considering the number of bacilli present in the animal body at the time of death, this bacillus is far more toxic than the observed strains of other tissue invading groups. Proteolytic action and tissue destruction were not detected in the guinea-pig body probably on account of the sparse proliferation of the bacilli, though a faint proteolytic odor may sometimes be noted. Edema production in connective tissue and muscles is marked; the edema is water-clear. No gas formation has been noted in the animal. Hemolytic action may be entirely absent or may be confined to a spot or two. Injection of the serous surfaces and of the suprarenals is intense. In accordance with a new system of nomenclature,[5] we propose for this bacillus the name *Reglillus progrediens.*

From the region of the wrist, a second new tissue-invading pathogen was isolated. It is a nonproteolytic anaerobe of high saccharolytic powers, and resembles *B. welchii* in its action on tissues. No organism of our acquaintance possesses sufficient characteristics in common with it to warrant its association in the same genus. For it we propose the name *Meyerillus sadowa.* It is an actively invading organism of the muscle-feeding type. It causes considerable muscle and connective tissue destruction in the guinea-pig, and but little gas and edema formations. The intestines are injected and bile-stained, the suprarenals injected and enlarged. The striking lesion is a multitude of hemorrhagic erosions on the stomach lining, resembling leopard spots. The bacilli are densely gram-positive heavy rods with square ends; in the animal body they vary in size and form no chains or spores.

These two species will be described in detail in a future paper.

A strain of sporogenes affinities was isolated from the muscles distal to the fracture; but this type of organism was not present in sufficient numbers to cause any gross evidences of proteolysis.

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5. Heller, H. H.: Suggestions Concerning a Rational Basis for the Classification of the Anaerobic Bacteria, J. Bacteriol. **5**:521 (Nov.) 1921; Certain Genera of the Clostridiaceae, J. Bacteriol. **7**:1 (Jan.) 1922.

No aerobes were found in the material at any point.

On the ninth day after the fracture occurred, exudate from the stump contained leukocytes and was microscopically sterile; but smears from the necrotic areas showed gram-positive sporulating rods resembling *Vibrion septique*, a gram-negative rod, and a few large cocci. Culture showed the presence of *Vibrion septique* and a proteolytic organism.

Much emphasis was laid during the war on the part played by the heavily fertilized soil of France in the causation of gas gangrene. As we here had to do with a much less severe wound than many of those encountered during the war, one containing no earth or other foreign material, and as we found so many species of anaerobes in the wound, an effort was made to investigate the conditions surrounding the accident.

The child had fallen from a high bench, near a street in a suburb of San Francisco, onto dry sandy earth covered with dry grass. Goats were pastured in the neighborhood and had perhaps often crossed the place where the accident occurred; but no manure was demonstrable in the close vicinity. The ground had probably not been cultivated for years. One would not think of it as a particularly dirty spot. Two samples of grass and two of earth were taken to the laboratory and were inoculated into meat medium. All gave a mixture of anaerobes on cultivation. These included heavy gram-positive, short, square-ended rods. All four cultures when inoculated onto milk gave prompt and decided stormy fermentation, which was caused by the short, gram-positive rods, establishing the identity of *B. welchii*. This organism in the meat cultures was killed out by heat, and the resulting meat cultures when twenty hours old were inoculated in 0.5 c.c. doses into the thighs of guinea-pigs. Two of these animals developed a very marked edema, and one of them which had been injected with a culture from grass died in twenty-four hours, and on section, its tissues showed evidence of great proteolytic action. The other was killed after twenty-four hours. The thigh inoculated contained gas and was partially digested. The whole ventral surface to the axillae was covered with a plaque of white serogelatinous edema, a half inch in thickness. This edema was not putrid and contained no gas. These infections were both evidently mixed proteolytic and nonproteolytic ones. *Vibrion septique* may be regarded as having been absent as it almost always causes death in the guinea-pig before the lapse of eighteen hours. Various unidentified anaerobes were cultivated from these guinea-pigs.

It must be remembered that the physician who received the case stated that the arm was wrapped in a towel that was "rather dirty," and that the family of the child lived near a barnyard. Nevertheless, we think that because of the findings in the grass and earth it may be

stated that abundant anaerobes may exist on the surface of uncultivated poor sandy soil, and that numbers of these are capable of surviving and multiplying in lacerated muscle, and that some of them may penetrate healthy tissue in proximity to such muscle, even when foreign matter such as soil is not present in the wound.

COMMENT

We have here to do with a mixed anaerobic infection which had as a focus lacerated muscle in the forearm. The organisms found are divisible into groups, as in the accompanying table:

GROUPS OF ORGANISMS

Flora Observed	Proteolytic	Nonproteolytic
Invasive in man in tissue proximal to wound	Reglillus progrediens	Vibrion septique Bacillus S
Invasive in guinea-pig, but not in man		B. welchii Meyerillus sadowa
Not invasive in guinea-pig or properties unknown	Sporogenes type	Small rod producing no gas Gram-negative rod producing little acid Bacillus S

Although the opinion most widely held early in the period of the war was that gas gangrene was a monospecific invasion, caused usually by *B. welchii,* workers who have since made careful bacteriologic studies of their material have emphasized that gangrenous invasions following war wounds are usually polyspecific. The interested reader will find the fullest account of such investigations in Weinberg and Séquin's [6] book and in the report of the Medical Research Committee [7] on anaerobic bacteria and infections. The cases of Weinberg and Séguin are the most carefully worked out and discussed. These authors describe more numerous and more highly polyspecific infections than do other workers This must, in all probability, be attributed to their technic. They use for isolation deep glucose agar shakes, wherein the flora is spread out like a map, and wherein relatively accurate estimates of the number of organisms of different sorts may be made. The British workers have employed surface methods almost entirely. These suffice admirably for *B. welchii* and for *Vibrion septique,* but sometimes fail to show the presence of other types.

6. Weinberg, M., and Séquin, P.: La Gangrène gazeuse, Paris, 1918.

7. Report No. 39 of the Committee on Bacteria and Infections, Medical Research Committee, London, 1919.

The ecology of bacterial organisms entering a sterile territory of rich food supply which has partially but not entirely lost its defensive powers against them is a most interesting study; and it is to be regretted that the exact distribution of these organisms was not more carefully mapped out in this case than it was. For purposes of an ecologic study, the arm investigated may be divided into various zones.

Zone 1. *The Immediate Foyer of the Wound.*—Into this, both aerobes and anaerobes were without doubt introduced. The condition of the tissue was anaerobic; the strict aerobes never developed; the facultatively anaerobic ones were probably all types to which the body had some resistance, and the defensive powers in the damaged tissue were sufficient to destroy them even in the presence of the rapidly developing toxins of the anaerobes. But several types of anaerobic organisms were apparently able to multiply unhindered in this damaged tissue, probably because they were types to which the body was unaccustomed, some of them, types which would probably not have been able to multiply in tissue so little damaged as was the muscle about the fractured bones, if they had not been defended by the toxins of their fellows.

Zone 2. *The Hand.*—The portion distal to the fracture was probably afforded a meager circulation for a considerable period of time after the accident occurred. Invaders capable of traveling along the blood vessels and lymph channels did so and reached the hand. They were the organisms that died after their first cultivation, and the minute rod that produced no gas, perhaps also *Vibrion septique*. These organisms caused the formation of a thick edema in the connective tissue and of a little gas in the region of the small muscles.

Zone 3. *The Wrist.*—As swelling in the region of the fracture increased, the circulation in the distal segment decreased, and some of the active muscle feeders (*B. welchii, Meyerillus sadowa* and the sporogenes-like organism) traveled downward in the muscle, some of which was contused, multiplying extensively and attacking it so severely as to produce gas but no gross tissue destruction, and effectually shutting off the circulation from the entire distal portion of the arm. Organisms found within this region cannot be considered as strongly invasive in their nature, merely because of this invasion of damaged muscle.

Zone 4. *The Section Between the Fracture and the Elbow.*—Here the contest between the tissues and the organisms was acute The blood supply was somewhat subnormal; the tissues were somewhat contused. A reservoir of necrotic, toxin-breeding muscle lay distal to this section. Apparently, only three organisms succeeded in invading this zone, *Vibrion septique,* the mysterious *Bacillus S,* that in the presence of the toxin of *Vibrion septique* was able to avail itself of the same means of distribution as that organism, and a toxic edema-former with slight proteolytic powers (*Reglillus progrediens*). That *B. welchii* was not represented in this zone may surprise some workers. Strains of this type of organism vary in pathogenicity. This was one of moderate pathogenicity for the guinea-pig. The strain *Meyerillus sadowa* was fully as pathogenic for the guinea-pigs as the Welch strain.

Zone 5. *The Upper Arm.*—Here *Vibrion septique* and *Bacillus S* multiplied with a fulminating rapidity and availed themselves of the blood and lymph channels for distribution. At the level of amputation, the blood vessels contained numerous bacilli, and *Vibrion septique,* at least, had invaded the

blood stream at the time of the operation. The tissue invasion at this point was slight. After amputation, the bacilli continued to multiply in the tissues of the stump; but the defensive forces were sufficient to prevent extensive necrosis of the tissue and gas formation.

Zone 6. *The Body.*—It is much to be regretted that blood cultures were not made of this case. There must have been a continuous pouring of organisms into the blood stream before the amputation; but it is a question how efficiently the blood defense disposed of them. Klose [8] found that in 60 per cent. of eighty cases of anaerobic wound infection anaerobic organisms were to be cultivated from the blood stream at various stages of the disease, and 51 per cent. of these patients recovered. Therefore, the defense of the body against the persistence of anaerobic bacilli in the blood stream is less than that against anthrax bacilli. On the other hand, the presence of anaerobic bacilli in the blood stream does not indicate so grave a prognosis as does than of anthrax bacilli.

An item of interest lies in the anatomic lesions in the arm. The gelatinous edema of the connective tissue and the black hemorrhages of the muscles were so typical of the lesions produced in the guinea-pig by the oedematiens strain "Joly" that even a very cautious worker would be tempted, especially after finding a large terminal oval spore-bearer and large rods with curved ends, to affirm the presence of that organism. But as far as is ascertainable, a bacillus of the oedematiens group was not present. This type of organism is easily isolated on account of its large colonies. None of the organisms isolated produced in the guinea-pig a black hemorrhagic discoloration like that noted in some of the muscles of the arm. *Vibrion septique* strains produce a less intense coloration in the guinea-pig. The discoloration in the arm muscles must be attributed to the more prolonged action and greater proliferation of *Vibrion septique* organisms in the muscle of a larger and more resistant animal than the guinea-pig. The edema noted in the connective tissue is readily referable to the combined action of the highly toxic edema-producing Reglillus strain and *Vibrion septique.*

The question of the incidence of gas infection in civil life is of interest. Von Hibler [9] lists fifteen strains of *B. welchii* that he isolated from human material. Of these, only two could be called the direct cause of the death of the patient. Both of them were infections after injury. He lists four strains of *Vibrion septique* type isolated by himself; and in three of these cases the organism was demonstrated to be the probable cause of death. He found Novy's bacillus once in a human case, and it was probably the cause of death.

8. Klose, F.: Ein Beitrag zur Kenntnis der durch die Gruppe der gas-oedem Bazillen erzeugten anaeroben Wundinfektion, Münch. med. Wchnschr. **64**:295, 1917.

9. Von Hibler, E.: Untersuchungen über pathogenen Anaeroben, Jena, 1908.

Ghon and Sachs [10] have investigated anaerobic infections occurring in civil life and report various anaerobic invaders.

Cases of anaerobic invasion exclusive of tetanus coming to necropsy in civil life may be classified into two groups. One group is that of patients weakened by sickness or operations who are invaded by their own intestinal bacteria. Such invasions, though they may be, and frequently are, polyspecific, usually have for their chief invader the Welch bacillus. This organism is a common human intestinal saprophyte. Occasionally, Welch bacillus infection follows the injection of drugs into the legs or buttocks. But systemic or local invasions following wound infections, under which head come puerperal infections, especially such invasions as have small foci, are frequently not caused by *B. welchii,* even though the latter organism may be found in the wound. The severity of the tissue destruction and the presence of foreign matter has much to do with the type of invader capable of multiplying in the first hours. The serious wounds caused by high explosives afford far more chance for the growth of *B. welchii* and other muscle feeders than do such cases as the one herewith reported. Welch bacillus infection among animals (except, perhaps, among young sheep) is apparently exceedingly rare, while *Vibrion septique* infection is common. Blackleg infection is found with some frequency among cattle and sheep and oedematiens group infection is noted occasionally among horses. The Medical Research Committee [11] and Sacquépée [12] have miminized the importance of the rôle of the Welch bacillus in war wounds.

The preferred habitat of the anaerobic invaders is of interest. The notable muscle feeders are *B. welchii* and *B. chauvoei.* They may proliferate metastatically, the latter more frequently than the former. *B. welchii* infections may frequently be controlled by excision of infected muscle, while blackleg infections may not. Organisms of the *Vibrion septique* group may feed on muscle, and they frequently do so; but they show a preference for connective tissue and for serous linings, and they also show a remarkable facility for spreading along the lymph and blood channels. Their invasions are, therefore, not to be controlled by excision of individual muscles as are Welch infections. Many of the organisms of the oedematiens group fail to spread rapidly from the site of inoculation and act by means of toxins that advance far before them. Some strains of *B. novyi* may kill

10. Ghon, A., and Sachs, M.: Beitrag zur Kenntnis der anaeroben Bakterien des Menchen zur Aetiologie des Gasbrandes, Centralbl. f. Bakteriol. **34**:288, 609; **35**:665; **36**:1,178, 1903.

11. Medical Research Committee, quoted by Caulfeild, A. H. W.: B. Perfringens: Toxin and Antitoxin Production, J. Inf. Dis. **27**:151 (Aug.) 1920.

12. Sacquépée, quoted by Caulfeild: Footnote 11, second reference.

guinea-pigs without any invasion at all. Other types, such as the bacillus of Ghon and Mucha and the oedematiens strain "Joly" possess very active invasive powers.

Therefore, it is evident that the prognosis of a gangrenous infection in man or animal depends very much on the specific anaerobes that are present in that process.

The value of persistence and careful observation should be emphasized in the investigation of mixed floras. The careful and scientific investigation of a gas gangrene case takes weeks, not hours. The bacteriologist who amiably complies with the clinician's impetuous demand for a diagnosis will usually have to reverse the diagnosis or change it several times. The bacteriologist who contents himself with finding in an invaded tissue Welch bacillus or *Vibrion septique* and who makes no effort to look farther adds nothing to the sum of human knowledge. There are plenty of pathogenic anaerobes still undiscovered. True, it is rare that unusual types invade alone; but unusual pathogens are worth isolating, studying and describing.

For the bacteriologist who is besieged by the clinician, anxious for the life of his patient, the following suggestions may be made. The generous administration to the patient of mixed Welch-vibrion septique-oedematiens serum should be suggested. Smears should be made and cultures taken from affected tissue remote from the wound. Guinea-pigs should be inoculated with fluid drawn aseptically from such tissue. If specific anaerobe antiserums of the three important types are available, three guinea-pigs should be protected, each with two serums in different groupings and all three of them should be inoculated in the thigh with tissue fluid, not with wound exudate, from the patient. In from twelve to eighteen hours, an answer of some value concerning the presence or absence of some one or two of the three important types may be formulated. This procedure is recommended by the British Medical Research Committee.

SUMMARY

The case herewith reported emphasizes the importance of bacteriologic examination early in compound fractures, even in civil life, by one especially skilled in anaerobic work. It shows also that all cases of compound fracture should be under observation in a hospital for at least the first two days after injury.

This case of gas gangrene, which was due to an infected compound fracture of the forearm, was diagnosed before amputation as a Welch bacillus infection.

Four anaerobic bacilli capable of rapid invasion in the guinea-pig body were isolated from the amputated arm. *B. welchii* had not invaded such tissue as was supplied with circulation. The principal invader

was *Vibrion septique,* which nearly caused the death of the patient after the amputation. There were two anaerobic bacilli that are guinea-pig invaders which are apparently new. No cocci or aerobic rods were present in the wound or surrounding tissue.

The area about the fracture had not been exposed to very dirty conditions, nor was a visible amount of foreign material introduced into the small wound made by the broken bone. There was, however, comminution of bone which may have had not only a mechanical but a chemical influence on the multiplication of the bacteria that were introduced into the neighborhood of the fracture.

A careful study of the process of invasion by anaerobic organisms in gas gangrene cases, a labor well nigh impossible in most war laboratories, is advisable when time and facilities for the study of anaerobes are available.